RISK FACTORS OF ROAD TRAFFIC ACCIDENTS IN SRI LANKA

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Thesis/Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree Master of Science in Business Statistics

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Sri Lanka

June 2020

DECLARATION

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Abstract

Road Traffic Accidents (RTAs) are one of the most prominent public health problems as it is a leading cause of death by injury and all deaths globally. This study therefore intended determine the risk factors associated with RTAs in Sri Lanka (2005 - 2019) based on data driven decision making (DDDM) which would be useful for decision makers. The results were obtained using analysis of 2 - way frequency tables, logistic regression and factor analysis. The percentage of fatal accidents have increased from 6.1% (2005 - 2008) to 7.2% (2013 - 2019), while damage have been dropped from 44.1% to 35.5% during the same period. The percentage of grievous accidents have an increasing trend by rising from 14.1% (2005 - 2008) to 21.8% (2013 - 2019), while minor accidents have been dropped from 35.7% to 35.5% during the same period. It was found that all the attributes of road characteristics, time & environmental characteristics, vehicle characteristics and among all the attributes of human & accident characteristics (except gender) have significant association on severity of accident. The gender of the driver does not significantly influence on the severity of accident. The seven variables of causes of RTAs identified by the Sri Lanka Police can be classified into two factors namely (i) negligence of pedestrians and other external reasons and (ii) lack of attention of the driver. This was confirmed by the confirmatory factor analysis. The odds of happening fatal accidents in wet road surface 1.109 times higher than that it occurs in dry road surface. The odds of happening fatal accidents during night with improper street lighting is 1.518 times higher than that it occurs during daylight. The inferences derived from this study would be very useful for policy makers in order to minimize RTAs in Sri Lanka.

Keywords: *Key Causes, Risk Factors, Road Traffic Accidents, Severity of Accident*

ACKNOWLEDGEMENTS

Apart from the effort of me, the success of this dissertation depends largely on the encouragement and guidelines of many others. I take this opportunity to express my gratitude to the people who have been instrumental in the successful completion of this dissertation.

First and foremost, I would like to give my gratitude to Prof. T. S. G. Peiris, Senior Professor in Applied Statistics, University of Moratuwa and the Course Coordinator of the M.Sc./Post Graduate Diploma in Business Statistics, for the valuable guidance and advices.

Also, my thankfulness to the Lecturer Panel of MSc. Business Statistics for providing the knowledge and guidance throughout the course.

I would like to express my thanks to Dr. Manjula Gunarathna, Head of Department of Social Statistics, Faculty of Social Sciences, University of Kelaniya for constant encouragement for the success of this dissertation.

My sincere gratitude to Department of Police, Sri Lanka for the provision of data regarding the Road Traffic Accidents.

Finally, an honorable mention goes to my family and friends for their support on me in completing this dissertation.

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LIST OF ABBREVIATIONS

AGFI	-	Adjusted Goodness of Fit Index
AIC	-	Akaike Information Criterion
BIC	-	Bayesian Information Criterion
CAIC	-	Consistent Version of Akaike Information Criterion
CFA	-	Confirmatory Factor Analysis
CFI	-	Comparative Fit Index
DALYs	-	Disability-Adjusted Life Years
EFA	-	Explanatory Factor Analysis
GDP	-	Gross Domestic Product
GFI	-	Goodness of Fit Index
GNP	-	Gross National Product
IHME	-	Institute for Health Metrics and Evaluation
MLF	-	Maximum Likelihood Factoring
NFI	-	Normed Fit Index
NNFI	-	Non-normed Fit Index
OR	-	Odds Ratio
PAF	-	Principle Axis Factoring
PCF	-	Component Factoring
PGFI	-	Goodness of Fit Index
PNFI	-	Parsimonious Normal Fit Index
RMSEA	-	Root Mean Square Error of Approximation
RMSR	-	Root Mean Square Residual
RTAs	-	Road Traffic Accidents
SRMR	-	Standardized Root Mean Square Residual
VIFs	-	Variance Inflation Factors
WHO	-	World Health Organization

CHAPTER 01

INTRODUCTION

1.1. Background of the Study

Road Traffic Accidents (RTAs) can be identified as one of the most prominent problems related to community well-being and a prominent factor that causes deaths through injury worldwide. The World Health Organization accentuated that, RTAs are a largely neglected child health problem as a large number of children and young adults between the age limit of 5 - 29 die as a result of RTAs (WHO, 2018a). RTAs place eighth as a prominent cause of death for people of all age groups exceeding the amount of deaths caused by HIV/AIDS, Tuberculosis, and Diarrheal Diseases. RTAs not only cause a large number of deaths but also create a loss of material in a physical and economic sense.

RTAs are rising steadily resulting in the loss of lives of approximately 1.35 million people each year. It has been estimated that every one minute, 2 people die and 95 people are either harshly injured or incurably disabled due to traffic accidents, globally. Furthermore, an estimated amount of 20 to 50 million people experiences minor injuries while many are left disabled. WHO (2004) mentioned that lower middle and upper middle income earning nations account for about 85% of the deaths and 90% of the annual Disability-Adjusted Life Years (DALYs) lost because of RTAs. The death rate due to RTAs was 2.6 times greater in the lower middle and upper middle income countries than in higher income countries, despite lower rates of vehicle ownership in lower middle and upper middle income nations in comparison to higher income earning nations. When stated relative to the population, lower middle and upper middle income countries experience 24.1 deaths per 100,000 population while higher income countries experience 9.2 deaths per 100,000 population (WHO, 2000). The current trend of RTAs suggest that it will take the third place in terms of contributing to the universal burden of injury and disease by the year 2020 (IHME, 2018). Based on the WHO (2013), most of the countries, especially the developing countries do not pay sufficient attention to

RTAs, road safety measures, and the challenges that come with the increased usage of private vehicles. A similar notion has been brought to attention by Jacobs et al. (2000), denoting that RTAs are increasing at a faster rate due to urbanization, increase in motorized vehicles, and the lagging development of road infrastructure in countries with developing economies.

The rise in the number of RTAs has resulted in increased economic disadvantage. Scholars (Hills & Jones-Lee, 1981; Anh & Dao, 2005) have suggested numerous methods to estimate the economic impact of RTAs and these methods include, the gross output method, the human capital method, the net output method, the life insurance method, the court award method, implicit public sector valuation and willingness to pay. However, a consensus about which method is most appropriate for estimating the cost of RTAs is absent. Mathers et al. (2002) stated that the cost of RTAs is estimated in lower income, middle income, and high income countries as 1%, 1.5%, and 2% of the GNP respectively. The cost of RTAs can be put into two categories as direct and indirect costs. US$ 518 billion has been estimated as the explicit economic cost of global road crashes while US$ 65 billion has been estimated as the explicit economic cost of road crashes in lower income countries and this amount exceeds the total annual amount received in development assistance (Mathers, et al., 2002). As per the report of the WHO (2000), European countries are responsible for 5% of the global death toll and exceed US$ 207 billion in terms of explicit costs caused by RTAs. Developing countries bear a cost of $100 which is about 1% - 3% of their GNP (Peden et al., 2004). The indirect costs associated with RTAs can be multiple times higher than the direct costs, however, prominent scholars (Mathers et al., 2002; Anh & Dao, 2005) have declared that indirect costs cannot be quantified.

As identified by the WHO (2013), which compares the RTAs among regions, it was found that the African region shows the greatest road traffic fatality rate. Within the African region, the annual road traffic fatality rate was reported to be 32.3 deaths per 100,000 people, while America, Europe, and South Asia reported 15.8 deaths per 100,000 people, 13.4 deaths per 100,000 people, and 16.6 deaths per 100,000 people respectively (WHO, 2013). As per the current trend in developing countries deaths caused by RTAs are greater than the number of lives lost due to Malaria and

Tuberculosis. The continuity of this trend suggests that by 2030 the fatality rate of RTAs will be greater than the human lives lost due to Malaria and Tuberculosis put together and even higher than the deaths caused by HIV/AIDS (The Economist, 2014). Thus as stated by the WHO (2018b), vulnerable road users and citizens of lower and middle income countries disproportionately bear the burden of RTAs as well as the deaths caused by RTAs and these growing number of deaths are fueled by transportation which is becoming exceedingly motorized. As per the WHO (2018b), between the periods of 2013 - 2016, no reduction in the deaths caused by RTAs was observed in lower income countries while 48 in middle and higher income countries showcased some reduction. An overall number of 104 countries showed an increase in the number of deaths caused by RTAs within this period. RTAs fall under the first five causes of mortality and morbidity in the South Asian Region (Amarasinghe & Dharmaratne, 2019).

1.2. RTAs in Sri Lanka

Sri Lanka which belongs to the South Asian Region and the upper middle income strata shows a prominent burden of damages and fatalities related to RTAs (WHO, 2015). The deaths caused by RTAs made up 2.8% of total deaths in Sri Lanka or 3,554 lost lives as per the WHO data published in 2017. The age-adjusted death rate was found to be 16.33 per 100,000 of the population. Amarasinghe and Dharmaratne (2019) mentioned that Sri Lanka is facing the burden of RTAs and associated injuries and deaths, due to an exponential growth in motorization on a static road system. Statistics of the Sri Lanka Police (n.d.) also displayed that an enormous increase has taken place in mobility and motorization in Sri Lanka during the last decade. A study done by Kopits and Cropper (2003) claimed that there would be a 150% increase in RTAs within the period of 2000 to 2020 in Sri Lanka. When considering the economic burden caused by RTAs in Sri Lanka, the Sri Lanka Police stated that 130 billion Rupees[1] is lost annually for the treatment of patients and due to the loss of labour caused by RTAs. Furthermore, 1.5% of the national GDP is lost annually and on average 4 people die daily as a result of RTAs. It was also found in Police statistics that more than 50 people

[1] US$ 760 million

experience serious or minor injuries daily due to traffic accidents. In addition to the value of the lost labour and human capital, it includes expenditures spent on medicine and health-care facilities, police costs, costs to mend damaged vehicles, and costs to repair road damages. In addition to these costs, the negative externalities associated with RTAs are unmeasurable.

Based on the above facts and figures, RTAs remain an ever-increasing trend and the alarming numbers of fatality recorded globally as well as in Sri Lanka, suggest that this will continue to be the case throughout the foreseeable future (WHO, 2018a). In comparison to the other leading causes of death in Sri Lanka, RTA is a controllable public health, economic and social problem. Yet, without sufficient knowledge of the seriousness of the problem, the risk of death and injury involved, the ability to carry out context-specific and appropriate interferences are thoroughly limited. The WHO (2018a) has emphasized that the under-reporting of deaths caused by RTAs which happens in many parts of the globe has resulted in insufficient priority being given to establishing road safety in comparison to other social, public health, and economic challenges. Furthermore, the annual death toll caused by RTAs surpasses the number of deaths caused by HIV/AIDS, Tuberculosis, and Diarrheal diseases yet the political commitment and financial investments given to ensure road safety is only a small fraction of that made to combat these diseases. Thus, it is of vast importance to acknowledge the intensifying situation involving road deaths and injuries and to take appropriate action. This study focuses on stimulating actions to establish road safety within the country through the identification of risk factors that associated with RTAs in Sri Lanka.

1.3. Risk Factors of RTAs

Prominent scholars (Pierce & Maunder, 1998; Baruah & Chaliha, 2015; Singh et al., 2013) conducted studies exploring the elements that influence RTAs globally. Research conducted by Nantulya and Reich (2002), claimed that pedestrians, passengers, and cyclists are the groups most affected by RTAs in developing countries as opposed to drivers. The increase in number of motor vehicles, the inadequacy of health-care infrastructure, poor transport facilities and inadequacy of proper traffic safety regulations are the major causes of RTAs and deaths caused by RTAs in developing countries according to their study. In addition, Pierce and Maunder (1998) have also pointed out various causes of RTAs; rapid urbanization and high growth rates of countries, irresponsible driving, poor road conditions, non-adherence to traffic regulation by motorists and the traffic officers (due to corruption) are among these causes. Furthermore, it was also discovered that the severe injuries caused by RTAs are more likely to be caused as a result of not using helmets or seat belts and over speeding of vehicles (Singh et al., 2013). A Study done by Komba (2006), has identified using cell phones while driving, failure in terms of following and respecting traffic regulations, driving without prior training or experience, poor vehicle conditions, driving old vehicles, and driving poorly serviced vehicles as major risk factors associated with traffic accidents. Furthermore, age, sex, careless driving, being a pedestrian, or a motorcyclist have been identified as risk factors of RTAs.

Multiple scholars (Kumarage et al., 2000; Komba., 2006; Komada et al., 2013) have carried out many studies to recognize the elements associated with fatal accidents. Among them, Kumarage et al. (2000) claimed that accidents related to speed are the most contributory to deadly accidents in Sri Lanka. Furthermore, Komba (2006), stated that defects in vehicles, driving aggressively, and driving on the wrong side of the road were major contributors of deadly accidents in Tanzania. A study done by Komada et al. (2013) found that slept deprivation among drivers is a significant contributor to fatal accidents. Parallel findings have also been made by Lucidi et al. (2013); stated that sleep related accidents are avoidable yet remain a major cause of traffic accidents. Their study found that young and inexperienced drivers are more vulnerable to RTAs whereas non-urban roads have more sleep-related accidents.

In addition to the above facts, drunk driving is also considered one of the most significant causes of RTAs in many countries. Petrie et al. (2011) studied the effect of alcohol consumption on traffic accidents in rural Australia. Findings indicated that the risky use of alcohol and traffic accidents showed a positive correlation. However, Callaghan et al. (2013) mentioned that a large number of studies were dedicated to alcohol consumption and driving safety but few focused on the use of drugs. Their study focused on drug-related accidents and fatality rates in California from 1990 to 2005.

Results revealed that individuals with alcohol and drug related disorders were at high risk of motor vehicle accidents. Callaghan et al. (2013) suggested that more interventions are required with a primary focus on drug use. A similar study has been carried out by Wilson et al. (2013) to identify the effect of alcohol use and distracted driving as a cause of traffic fatalities. They emphasized the negative effects of this trend in order to form policies to counter distracted driving.

However, it can also be stated that different studies related to RTAs produce varying results and conclusions (Ren, 2013; Jones et al., 2003; Noland, 2003). Ren (2013) stated that RTAs are caused by human error and concluded that human error is a major reason behind RTAs. As an opposite view to the Ren (2013) and Jones et al. (2003) claimed that geographical variations, such as size and age of population, road length, number of cars, per capita income, traffic counts, and material deprivation are important indicators of mortality and morbidity rates in RTAs. The study was carried out based on traffic data of England and Wales, and it demonstrated the importance of a geographical approach rather than a more conventional road section study. Furthermore, Noland (2003) found that there was no direct correlation between infrastructure changes, such as the addition of lanes, change in lane widths, and traffic fatalities. He suggested that factors such as age, use of alcohol, use of seatbelts, and medical technology played a far more important role than the infrastructure itself. Nevertheless, studies done by different scholars (Conesa et al., 2013; Liu, 2013) in different situations have identified poor lighting, inadequate visibility, improper designs, inefficient traffic administration, bad weather conditions, poorly lit roads, lack of street lighting, absence of warning systems, mobility of the population, traffic density, and the proportion of paved roads, motorways, and express roads as additional risk factors of road fatalities.

Based on the above facts, factors that are associated with RTAs vary from country-to-country and region-to-region. Additionally, risk factors that affect RTAs also differ due to climate changes, geographical attributes, attitudes of people, and various vehicle conditions. These factors also have the potential to change over time. Thus, deciding the risk factors associated with a certain destination is a complex process. For instance, a study conducted by Somasundaraswaran (2006) and Kumarage et al. (2000) mentioned contrasting risk factors of Sri Lankan RTAs that are no longer particularly relevant to current trends. This is so because road conditions and the manner in which vehicles are used are bound to rapid change. Consequently, the risk factors associated with RTAs may be different in comparison to previous studies. Thus, it is important to identify and provide solutions for the risk factors of RTAs in current Sri Lanka.

1.4. Present Situation of RTAs in Sri Lanka

As per the statistics of the Sri Lankan Police, RTAs are a major public health problem in Sri Lanka that causes many deaths and injuries. The common factors associated with RTAs are generally considered as various factors related to human nature and behavior, infrastructure inadequacies, defects in vehicles, diverse environmental and weather factors, and constraints of the police.

Despite traffic law implementations, technological advances, and improvements in the traffic education systems, the number of traffic fatalities have not decreased substantially over the year. This indicates that although efforts are being made in the right direction, there is a lack of overall understanding of all the contributing factors and their interaction with each other.

In order to establish programmes that make the optimum use of the funds and trained staff and to make positive progress towards meeting safety performance targets, it is vital that decision-makers gain a clear understanding of the manner in which various factors affect fatality trends. While the task of addressing transportation safety is handled by the Department of Police, each approaches the challenge of tackling RTAs from a different perspective. For instance, analyzing ways to strengthen the safety of the transportation system as a whole. By comparison, the Sri Lanka Police (n.d.) focuses on establishing laws that ensure that the users of the transportation system are protected from the actions of the individuals inside motor vehicles. Furthermore, public health officials focus on the prevention and treatment of injuries when RTAs occur.

Multiple explanations have been presented as an explanation for the reduction in crashes seen in recent years. Increased use of safety belts, safer vehicles, and better roads, strengthened funding for safety infrastructure improvements have been identified along with other factors as probable causes for the reduction seen in RTAs. Yet it has been found that roads are becoming deadlier by the year through the statistics compiled by the National Police Department. The Sri Lankan Police have identified 25 causes for RTAs. Those reasons are given in table 1.1 However, the direct impact of each attribute has not been investigated. It is important to identify the key causes out of the causes listed here in order to carry out immediate actions to minimize RTAs in Sri Lanka, the deaths caused and the cost incurred by society due to RTAs.

Table 1. 1: Causes of RTAs

Recklessness of the driver
Negligent of the driver
Indiscipline driving
Lack of knowledge (road rules and regulations, road conditions, weather conditions, conditions of the vehicle, knowledge regarding apparatus, controls, equipment)
Human error
Fatigue or stress
Road infrastructure defects
Not planning the trip
Duty poor health condition
Lack of driving experience and skills
Driving under the influence of alcohol
Failure to check power
Speeding
Not wearing the safety belt
Pedestrians not following road rules
Not following the indications of traffic lights
Not knowing the meanings of the different road signs markings signals
Lack of skills driving during rains, winds, fog and mist
Failure to obey road rules and regulations
Driving after taking medication
Trying to beat uptime
Failure in respecting the rights of others
Failure in recognizing civic responsibility
Unsatisfactory enforcement by some police officer
Not keeping the proper distance

Source: Sri Lanka Police, (n.d.)

1.5. Significance of the Study

The United Nations Summit on Sustainable development listed seventeen goals under the new sustainable development agenda. Among these seventeen goals, two goals are particularly related to ensuring road traffic safety. Target 3.6 states that the deaths and injuries cause by RTAs should be reduced to half of its current number by the year 2020. This goal falls under goal number three which states that healthy lives and higher wellbeing should be promoted among all age groups. Furthermore, target 11.2 stresses on the importance of establishing access to not only safe but also affordable, expanded and improved transportation systems with special attention being given to the needs of citizens in vulnerable situations, women, children, differently abled citizens and older citizens by the year 2030. This sub-target falls under the main target number eleven which states that cities as well as other human settlements should be made sustainable, inclusive, safe and resilient. Thus it is evident that RTAs are a significant public health challenge that requires adequate efforts to effective as well as long-lasting prevention.

Identifying risk factors of RTAs promote greater awareness, ensures that the government, industries, international agencies, and non-government organizations make well-informed decisions; so that policies proven in a scientific sense are carried out to prevent RTAs.

Identifying risk factors also promote a change in the manner in which the problem of RTAs is viewed and approached creating an increased probability for successful prevention. The view that RTAs are the cost of achieving mobility as well as development must be changed to a more all-inclusive notion that focuses on the prevention of RTAs through systematic action and efforts at all levels within the system of transportation.

Identification of risk factors also contributes to strengthen organizations and to generate sound and effective partnerships that promote safety within the road traffic system. Such partnerships should occur within the government, horizontally among diverse sectors and vertically among diverse levels. This means carrying out close partnerships between sectors such as the public health sector, transport, finance, and the legal sector as well as other sectors concerned. In addition, such partnerships should also occur between various government and non-government organizations.

1.6. Research Objectives

On the view of above explanations in details, the objectives of this study are;

i. To describe the characteristics of RTAs in Sri Lanka

ii. To identify the key factors of RTAs in Sri Lanka

iii. To determine the risk factors related with RTAs in Sri Lanka

1.7. Outline of the Dissertation

This research is classified into seven chapters as the first chapter includes the background of the study which focuses on the current trend of RTAs. The second chapter contains literature reviews on RTAs done by prominent scholars. The third chapter consists of the research methodology. Forth to sixth chapters emphasize on achieving the three objectives of this study. The fourth chapter describes the characteristics of RTAs during the period of 2005 - 2019. The fifth chapter focuses on identifying the key factors of RTAs and the sixth chapter aims to determine the risk factors associated with RTAs in Sri Lanka during the period of 2005 - 2019. Finally, the seventh chapter describes the conclusion and recommendations derived from the statistical analysis along with a few suggestions.

CHAPTER 02

LITERATURE REVIEW

This chapter investigates and critically evaluates the past studies on RTAs in the world as well as in Sri Lanka done by the prominent scholars and world recognized organizations.

2.1. Burden of Diseases and Injuries

When making decisions and policies related to healthcare and well-being it is important to study and analyze the weight of injury and diseases and the risk elements responsible for them. A categorized list of causes of death in the world by WHO (2018c) is given in Annexure I.

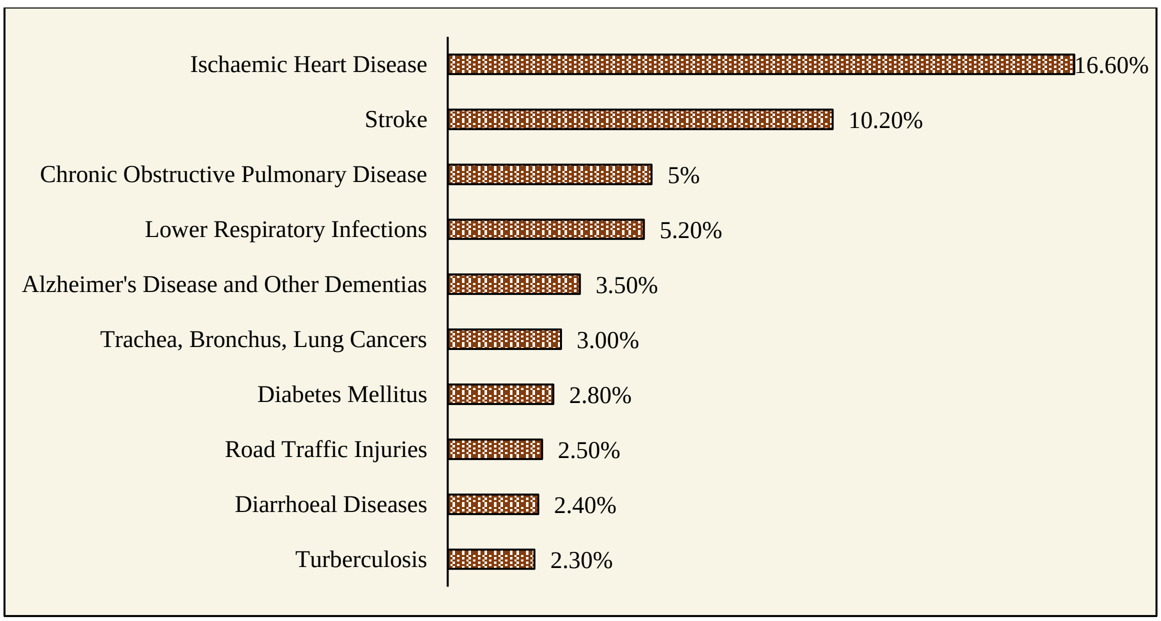

Figure 2. 1: Leading Causes of Deaths All Ages

Source: WHO (2018a)

These causes are broken into three major cause groups. Group I includes diseases that are infectious, perinatal, maternal, and conditions related to nutrition, Group II includes non -

communicable diseases and Group III includes injuries. Group III or rather the injury component is broken into two groups as intentional injuries and unintentional injuries. Unintentional injuries is the sub-group under which RTAs are categorized (Annexure I).

RTAs hold the eighth place in terms of causing loss of human lives for all age categories worldwide and this is shown in figure 2.1. RTAs are responsible for more lost lives even surpassing the number of lives lost to diseases such as diarrheal diseases, HIV and Tuberculosis.

2.1.1. The Global Burden of Unintentional Injuries

Injuries caused 16,000 deaths daily or over 5 million deaths annually becoming a major health-care problem for every country (WHO, 2017). Injuries that are unintentional are experienced by 61 per every 100,000 people. Out of the 15 listed causes of death for people between 15 - 19 years of age, five are explicitly related to unintentional injuries and these five include RTAs, drowning, poisonings, falls and burnings (WHO, 2017). While infectious diseases have greatly been reduced by prevention and early intervention methods adopted on a global scale, injuries that are unintentional remain a prominent health-care problem and continue to increase in number (Chandran et al., 2010). Unintentional injuries can be held responsible for 6.6% of the universal burden of mortality and over 3.9 million lives are lost annually as a result of unintentional injuries.

The death rate caused by injuries that are unintentional by WHO region is portrayed in Figure 2.2. The greatest rate is found in the Southeast Asian region causing 80 deaths per every 100,000 persons and lowest rate is seen in the American region causing 39 deaths per every 100,000 persons. Over 1.6 billion people reside in the Southeast Asian region making it the most populated region, explaining the high burden of unintentional injuries that occur within this region. However Chandran et al. (2010) stated that nations with incompetent facilities of data infrastructure are likely to undercount injuries, negatively affecting the accuracy of the comparison of injuries carried out across regions.

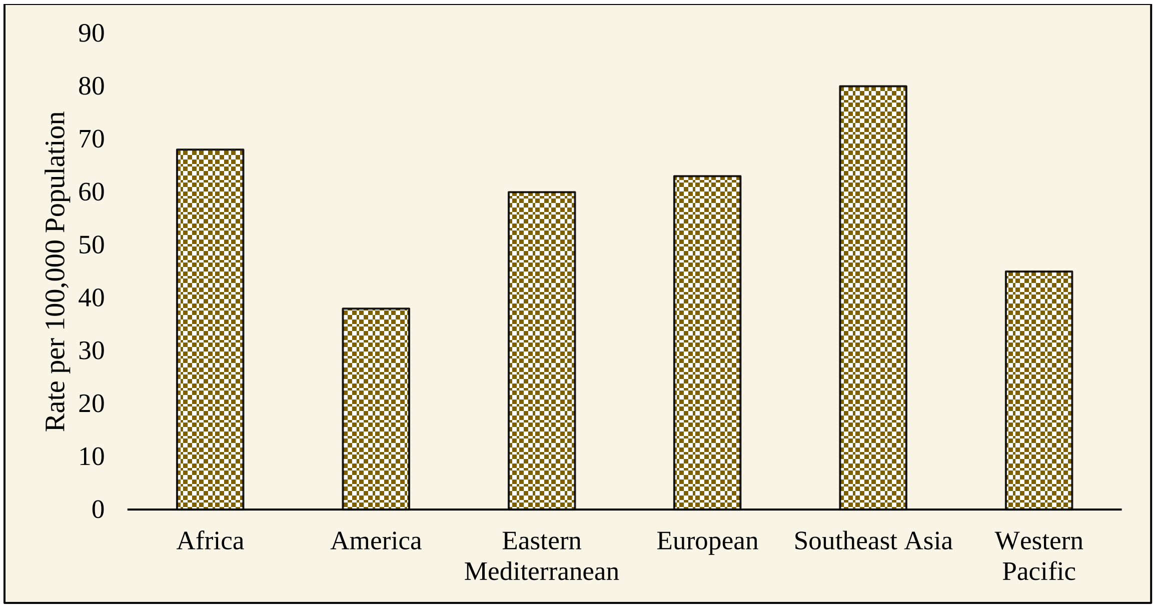

Figure 2. 2: Unintentional Injury Death Rate by WHO Regions

Source: Chandran et al. (2010)

Table 2. 1: Percentage of Unintentional Injury Deaths by WHO Regions

Causes	**Africa**	**Europe**	**Eastern Mediterranean**	**Southeast Asia**	**Western Pacific**	**Other**
Road Injuries	41	45	45	23	23	40
Drowning	13	7	9	6	8	16
Falls	4	12	8	14	9	16
Fires	10	2	9	4	14	2
Poisoning	8	7	5	19	7	7
Other	24	27	24	34	39	19

Source: Chandran et al. (2010)

RTAs can be held responsible for the lost lives of nearly 1.3 million persons each year amounting to a rate of mortality of almost 20 per 100,000 persons annually, making it clear that injuries caused by RTAs hold a major fraction of unintentional deaths as showcased in table 2.1 (WHO, 2017).

Moreover, injuries that are unintentional can be held accountable for more than 138 million Disability-Adjusted Life Years (DALYs)[2] annually (WHO, 2017). As shown in table 2.2; Africa, Southeast Asia and Eastern Mediterranean has a rate of DALY loss which is twice as higher than the in American regions. Thus it is clear that RTAs can be held responsible for nearly 1/3 of unintentional injury DALYs within all geographical regions.

Table 2. 2: Global Injury DALYs (per 100,000) and Rate Ratios (in parentheses) by WHO Region

	WHO Region						
Injury Type	**America**	**Africa**	**Southeast Asia**	**Eaters Mediterranean**	**Europe**	**Western Pacific**	**Global Rate**
Unintentional Injury	1,258 (1.0)	2,741 (2.2)	3,065 (2.4)	2,823 (2.2)	1,647 (1.3)	1,532 (1.2)	2,153
Road Traffic Injury	524 (1.0)	969 (1.8)	658 (1.3)	985 (1.9)	417 (0.8)	553 (1.1)	640
Fall	138 (1.0)	134 (1.0)	384 (2.8)	344 (2.5)	230 (1.7)	270 (2.0)	267
Fires	28 (1.0)	273 (9.7)	395 (14.0)	252 (8.9)	69 (2.4)	28 (1.0)	175
Drowning	71 (1.0)	247 (3.5)	164 (2.3)	179 (2.5)	90 (1.3)	218 (3.1)	167
Poisoning	66 (1.0)	155 (2.3)	110 (1.7)	78 (1.2)	246 (3.7)	74 (1.1)	116
Other	431 (1.0)	962 (2.2)	1,354 (3.1)	984 (2.3)	596 (1.4)	389 (0.9)	788

Source: Ramirez et al. (2012)

Not only among the unintentional injuries but also current trend claimed that by the year 2020, injuries caused by RTAs are likely to hold the third place as a leading cause of DALYs lost (Table 2.3).

[2] Sum of years of potential life lost due to premature mortality and the years of productive life lost due to disability

Table 2. 3: DALYs for the 10 Leading Causes of the Global Burden of Disease

Rank	Disease or Injury
1	Ischaemic Heart Disease
2	Unipolar Major Depression
3	Road Traffic Injuries
4	Cerebrovascular Disease
5	Chronic Obstructive Pulmonary Disease
6	Lower Repiratory Infections
7	Tuberculosis
8	War
9	Diarrhoeal Disease
10	HIV

Source: WHO (2018a)

Lives that are annually lost as a result of RTAs have risen to 1.35 million as per the claims of the WHO (2018a). This amounts to almost 3,700 persons losing their lives on the roads daily, and more people being left injured, disabled or suffering from life changing and long-lasting damages to their bodies. Losses of this nature take a massive toll not just on families but also on entire communities. The expenditures spent on emergency response and healthcare and the cost of human misery is massive (WHO 2018a).

Road safety has been recognized by the 2030 Agenda for Sustainable Development as a precondition to ensure strengthened well-being and healthy lives and to create inclusive, sustainable and resilient cities. Road traffic mortality is among one of the five indicators showcasing stalled progress as per the 43 SDG indicators related to health tracked in the 2019 world health statistics (Annexure II).

The WHO (2018a) also stated that the disabilities and injuries that take place due to RTAs and the safety of roads influence other issues related to community well-being (Figure 2.1) as these factors contribute to hindrance of human activity. Diseases like diabetes, chronic obstructive pulmonary diseases, strokes and heart diseases become wide spread due to selfimposed limitations to walking, cycling, taking public transport by citizens and increased motorization has also been linked to illnesses in the respiratory system. Ensuring Road traffic safety and supporting active travel also contributes to reducing the number of preventable deaths (WHO, 2018a). Thus RTAs are indeed a prominent health-care problem which has a major influence on the universal health situation.

2.2. Background of RTAs

Progress in reducing road traffic deaths over the last few years vary significantly between different regions and countries of the world. Countries in Africa and Southeast Asia have exceed the global rate of road traffic deaths indicating a rate of 20.7 and 26.6 respectively (Figure 2.3).

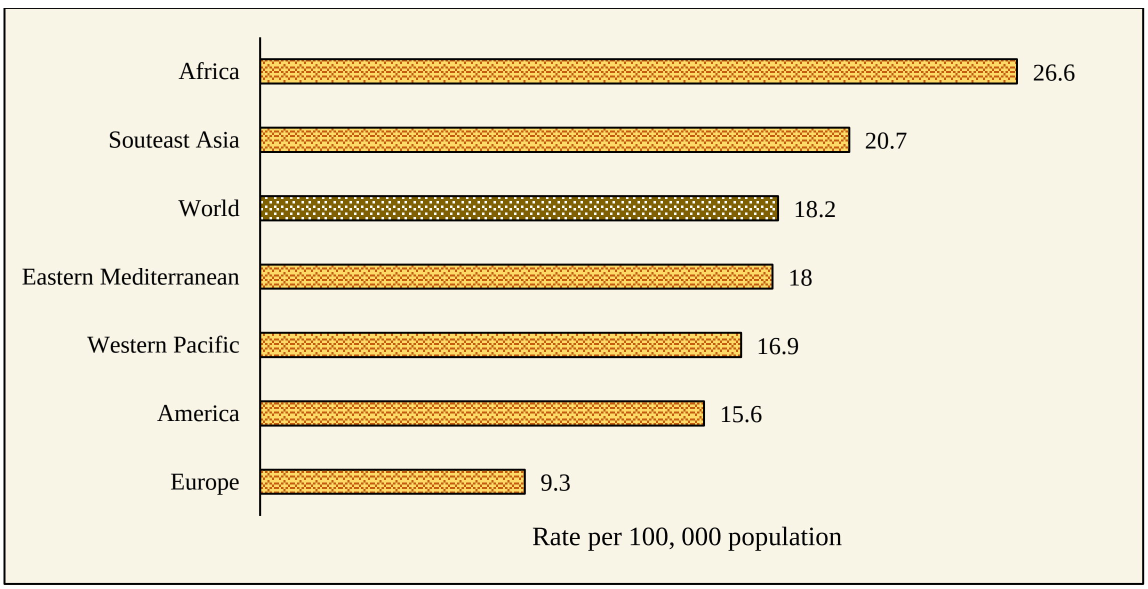

Figure 2. 3: Rate of Road Traffic Deaths by WHO Regions

Source: WHO (2018a)

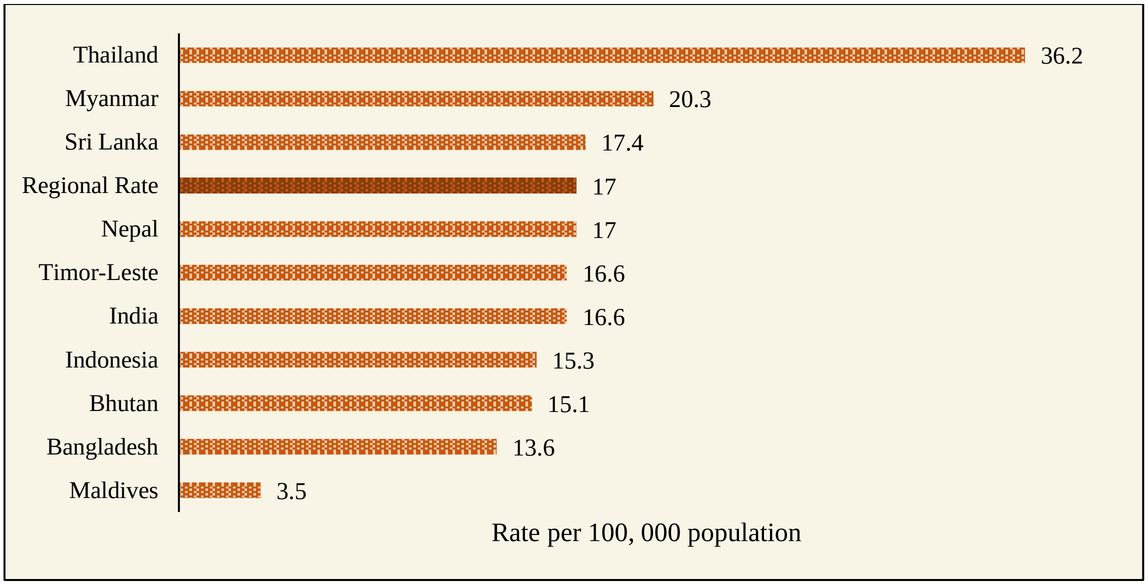

Figure 2. 4: Rate of Road Traffic Deaths by Southeast Asian Region

Source: WHO (2016)

Lives lost in the Southeast Asian region in traffic accidents take up 25% of the world's deaths cause by RTAs and add up to about 316,000 annual deaths as per the claims of the WHO (2016). The global rate of traffic fatality is 18.2 per 100,000 persons and the traffic fatality rate within the Southeast Asian region stand at 17.0 (Figure 2.3 & 2.4). Yet there is a noteworthy variation in the rate of fatality across the region varying from 3.5 per 100,000 in Maldives and 36.2 per 100,000 in Thailand. As demonstrated in figure 2.4 Thailand, Myanmar and Sri Lanka surpass the traffic fatality rate of the South East Asian region. A comparison of these three nations as shown in table 2.4 suggest that Sri Lanka has the greatest rate of population, road and vehicle density.

As per the WHO (2015), the vehicle population ratio or the amount of registered automobiles per 1000 persons is a prominent indicator of exposure to risk of RTAs (WHO, 2015). Greater number of vehicles suggest the need for more roads and expanded traffic safety and protection measures.

Table 2. 4: Population and Road Density of Southeast Asian Region Countries

Country	Population Density[3] (per square km)	Road Density[4] (km/100 sq.km)	Vehicle Density[5] (per square km)
Sri Lanka	346	173.9	109.73
Myanmar	82	5.6	10.03
Thailand	136	35.24	72.10

Source: The World Bank (2019)

According to the report given by the Department of National Planning (2017) it was found that 3,000km of Sri Lanka roads within the national road network has surpassed the traffic volume of 10,000 vehicles per day. Roads situated in urban areas surpass their service capacity during peak hours. More vehicles flock the roads as a result of new trips generated through economic activity. Measures such as moving freight to other modes of transportation like railway should be taken in order to avoid the rapid deterioration of rehabilitated roads and the added pressure to the road network system created by increasing freight transportation. A large fraction of the roads found in urban areas and link roads still remain mere two-way single carriageway roads. The capacity of these roads per one direction is limited to 1,140 automobiles per hour. The impossibility to expand roads horizontally as a result of other landscape developments in urban areas remain a major problem. Developing roads vertically requires massive investments Sri Lanka as a developing nation cannot afford. Thus it is clear that neither the expansion of roads nor the reduction in the number of auto mobiles can be presented as a solution to reduce RTAs and other diverse methods to minimize RTAs must be adopted. As per the WHO (2018c) it is important to develop assimilated road safety and public mobility measures to reduce RTAs. However, before road safety strategies can be developed it is important to identify the characteristics, key factors and risk factors associated with RTAs.

[3] people per sq. km of land area
[4] km of road per sq. km of land area
[5] vehicle per sq.km of land area

2.3. Behaviour of RTAs in Sri Lanka

When analyzing the behavior of RTAs in Sri Lanka, a considerable change can be seen within the period of 2001-2019 as shown in figure 2.5.

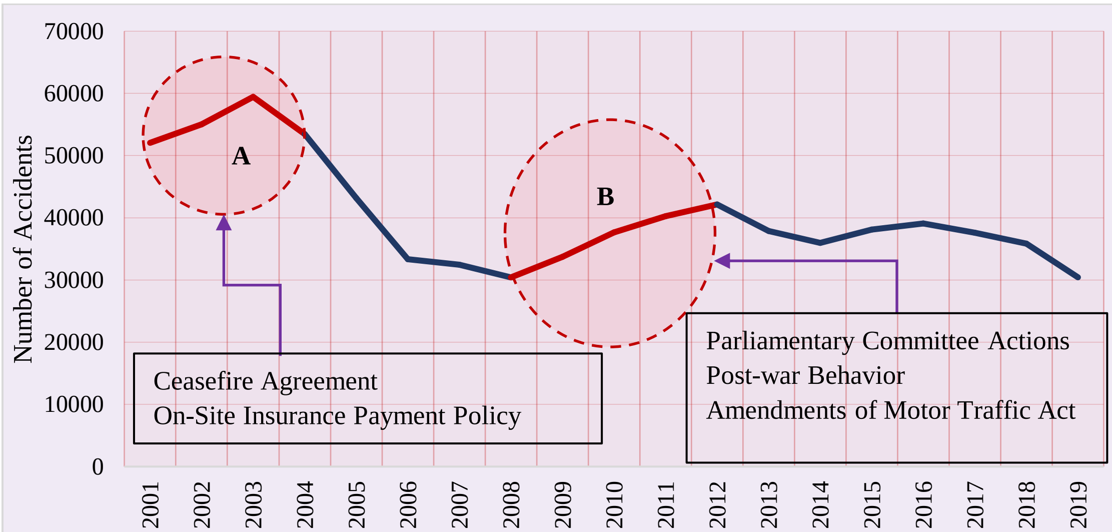

Figure 2. 5: Total RTAs (2001 - 2019)

The section "A" of the figure indicates the highest rate of reported RTAs in Sri Lanka during the period of 2001 - 2019. In the year 2002 an agreement by the name 'ceasefire' was signed with international negotiation and the agreement could be the reason for high rates of RTAs during this period. As a results of this agreement, police roadblocks and check points were removed and people had freedom to travel anywhere. The on-site insurance payment scheme introduced by local insurance companies in the year 2002 which paid instant insurance claims without a report from the police could also be a reason for the decrease in RTAs after 2003 (Dharmaratne et al., 2015). Thus, under-reporting of the RTAs increased due to this on-the-spot insurance policy. However, after 2003, continuous decreases in the number of RTAs could be seen until to the year 2006. Dharmaratne et al. (2015), claimed this reduction could be a result of a larger fraction of RTAs being unreported.

From the period of 2006 - 2008, there was a decreasing trend in RTAs and this has upturned after 2008. In the latter part of 2005 the civil war in the country worsened until the government carried out major scale military offensives to battle against the LTTE at the beginning of 2006. Therefore, during this period the security in the road network system in Sri Lanka was tightened. As a results of this, as seen in the figure 2.5, the RTAs in Sri Lanka showed a significant decrease during the period of 2006 to 2008. Additionally, in 2007 a group that consisted of parliamentary officials were nominated to carry out a survey to find reasons for RTAs in Sri Lanka. This lead to an increase in the reported cases of RTAs by the end of the year 2007 (Dharmaratne et al., 2015). Also Gunawardane and Dharmaratne (2013), mentioned that the increasing trend seen in 2009 might be due to the amendment in the motor traffic act made in 2009, making it compulsory for drivers to inform the nearest police station if a crash takes place. This explains the fact that the increase in the reported RTAs was mainly among damage only crashes. Thus, it can be concluded that the actions of the parliamentary committee, the end of the civil war in 2009 and the amendments of motor traffic act created an increase in the reported crashes.

From the period of 2012 - 2019, the RTAs in Sri Lanka gradually decreased. Within this period the lowest rate of RTAs was reported in the year 2019. RTAs in Sri Lanka stand at a trend supposedly decreasing as a result of under-reporting. However, all fatalities are reported to the Department of Police and the existing data on grievous accidents are nearly accurate as 95% of those who are seriously wounded are admitted to public health-care facilities. Analyzing these facts bring to light a major irregularity between the actual number of RTAs that take place and the number of RTAs being reported.

The introduction of an insurance policy system for motorists to promptly claim insurance has actually reduced the amount of traffic accidents being reported to the Police. Sri Lanka Police mentioned that, according to the statistics of insurance companies in Sri Lanka, there are at least 500,000 road accidents that happen in Sri Lanka every year. Nevertheless, the number reported to the Police is much less. The data available at the Sri Lanka Police accounts for only about 40,000 accidents per year. The reason for this under-reporting can be traced to the fact that driver being required to spend a large amount of time at the crash-cite until the police finishes their investigation. In a case where a report from the police is needed for insurance requirements the drivers are asked to wait for a number of days. Also when fatal RTAs occur; an investigation needs to be conducted, a postmortem needs to be performed, and a legal process needs to be followed, which take about three to four years. Other than that, the victims will have to file separate cases to claim damages and compensation.

Another reason of the under-reporting of RTAs is the process involving traffic accident registration. International Traffic Safety Data and Analysis Group: Derriks and Mak (2007), presented the process of registration of an accident (Figure 2.6). As demonstrate in figure 2.6, Derriks and Mak (2007) stated that when an accident occurs, depending on the nature of the accident the police services will be called and a standardized form will be completed and emergency services too will be called if the nature of the accident requires their attention. However there are cases in which the Police will not be called. Derriks and Mak (2007) also stated that in a case of an accident the police does not come to the location of the accident at all times as the availability of agents vary according to the nature of the accident and other situations which require their instant attention. Reporting serious accidents is of vast importance, for instance in the Netherlands the Police is present for almost 25% of the accidents that take place (Derriks & Mak, 2007). If the parties involving the accident claim that they are capable of coordinating the accident by themselves an administrative official will be left behind implying that the arrival of police agents do not always follow official registrations. The administrative official who is left behind will make sure that the financial aspect of the accident is sorted by filling out an insurance statement. Details like the cause and geographical specifications of the crash site will not be recorded by the police probably due to lack of interest (Derriks & Mak, 2007).

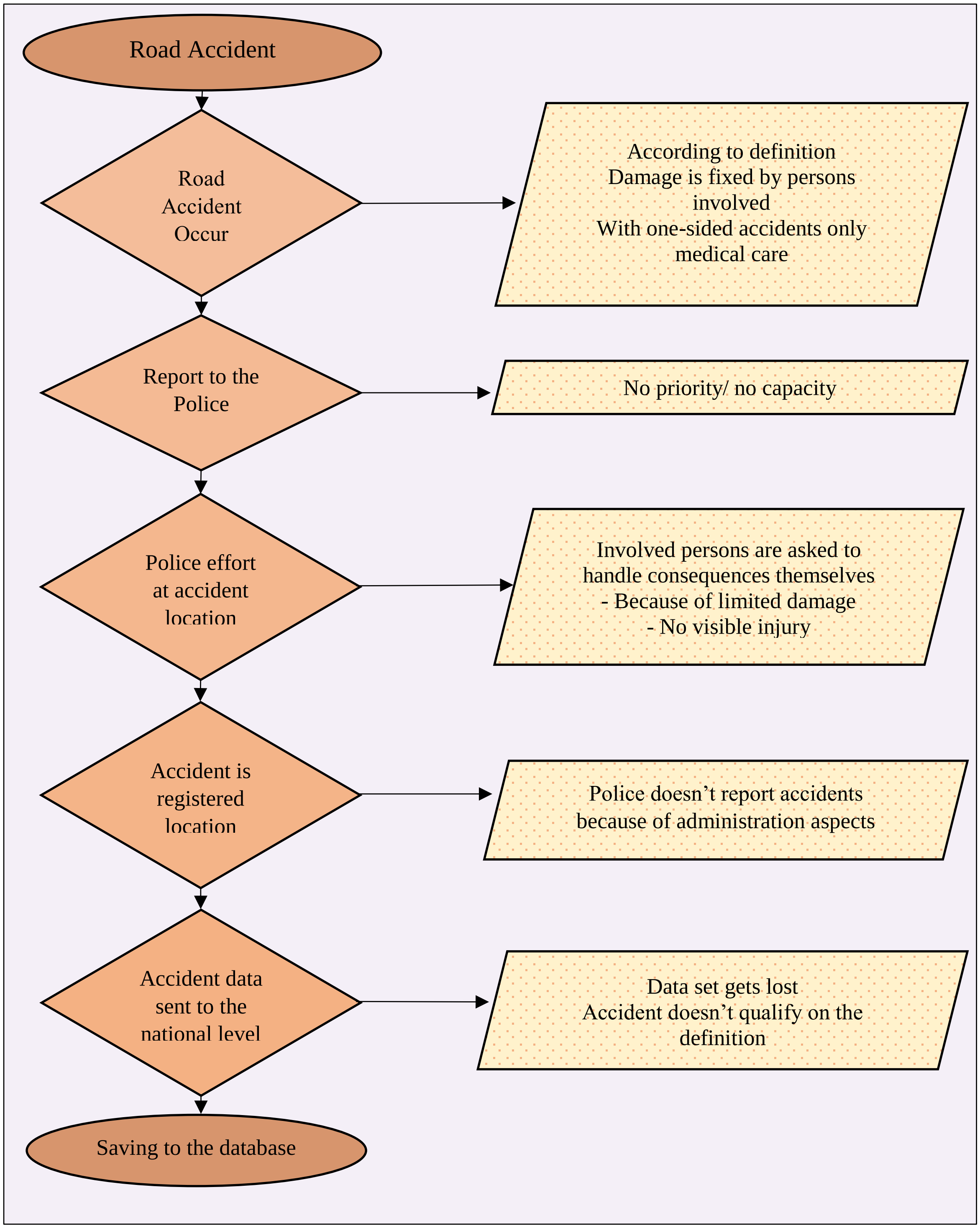

Figure 2. 6: Registration Process of an Accident

Source: Derriks and Mak (2007)

In conclusion, it is clear that the nature of this process may result in many accidents being under-reported. In order to improve the reporting of RTAs in Sri Lanka, Dharmaratne et al. (2015) suggested that the number of officers in the Department of Traffic Police should be increased and Agents should be trained to be present at the crash sites as fast as possible in order to be able to record all RTAs and hand out instant reports for insurance matters. Furthermore a police report should be made a requirement to obtain insurance payments.

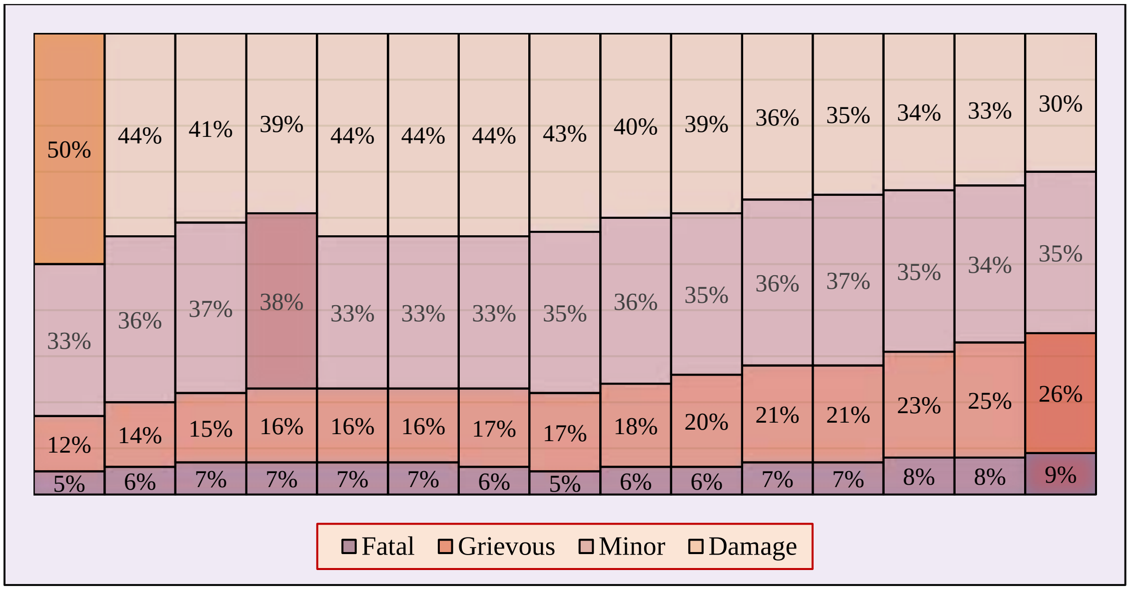

Figure 2. 7: RTAs by Types of Crashes (2005 - 2019)

The registered RTAs in Sri Lanka by the types of crashes during the period of 2005 - 2019, is shown in figure 2.7. Among the total number of registered RTAs in each year, damage accidents represented the highest proportion than the others. However, moving from year 2005 to 2019, there is a gradual decrease in damage accidents. It can be assumed that this reduction is due to the under reporting of the damage crashes, as the party that bears the damage would not report the accident to the police if they can cover the damage through the insurance scheme. Whereas, Kumarage et al. (2003) stated that nearly all accidents that are grievous and fatal are reported making the analysis of numbers of these accidents relatively reliable. The rate of the grievous and fatal accidents show an increasing trend during the period of 2005 - 2019. Year 2019 has the highest rate of grievous and fatal

RTAs. Thus based on the above facts it can assumed that there is an increasing trend of road accidents in Sri Lanka.

Therefore, it is a timely requirement to pay attention to this public, social and economic problem through identification of the characteristics, key factors and risk factors which are associated with RTAs in Sri Lanka.

2.4. Factors Associated with RTAs

Road accidents can be happen due to the different kind of reasons such as faults done by road users, road, weather and vehicle conditions. Robertson (1998) claimed that these factors might act as isolated as well as combination with one another, with the result of poly-causal.

Table 2. 5: Summary of Previous Research done in Different Countries

Researcher	Methodology	Findings
Nasiri et al. (2019)	Population based cross sectional study, all road traffic accidents in the South of Kerman during the period from 2013 to 2017. Logistic regression was used for the analysis, the type of incident was defined as a two-way dependent variable, with the code number 1 - death and 0 - injuries. Type of accidents, drivers' level of education, season, type of road, cause of accident, year of accident, and occurrence on a holiday or other days were all considered as independent variables.	Chances of death were higher in road accidents on main roads than on rural roads. In terms of the seasons of occurrence, death rates were higher in autumn than in winter. Among the effective factors, over speed and deviation to the left lane were more likely to lead to death than drowsiness and inattention to the front.
Liu et al. (2018)	Secondary data based on the period of 2004 - 2015 in China. Number of serious road accidents were consider as dependent variable and environmental, road and driver characteristics were consider as independent variables. Among the characteristics; professional	Results of the study revealed that terrain, overload, professional driver, large vehicles and fatigue as the significant risk factors on serious RTAs in China.

Researcher	Methodology	Findings
	driver, drink and drive, type of vehicle, fatigue, brake faults in the vehicle, overload, region, weather condition, terrain and road characteristics were selected as the dependent variables by using the Spearman's correlation. To recognize the risk factors of serious RTAs negative binomial regression analysis was conducted.	
Shakeer Kahn et al. (2017)	Study based on the primary data cross sectional study with victims of road traffic accidents admitted in Tirupati Hospital. The study period based on during June 2013 to May 2014 for one year where 820 victims of RTAs. Descriptive Statistics Techniques used for the data analysis	Not using seat belts, influence of alcohol, listening to music while driving, over speed have identify as the risk factors of RTAs
Rovsek et al. (2017)	Secondary data from the period of 2005 to 2009 in Slovenia including 220,578 accidents. Classification & Regression Tree (CART) algorithm was used to identify the risk factors	This study claimed that the road accidents are caused by not only isolated factors but also combination of risk factors. Study have highlighted that driving wrong side or lane, human errors, speed driving as important combine risk factors of RTAs in Slovenia.
Wang et al. (2017)	5 year based case control accident dataset was used this analysis in Wuhan City. Study focused on environmental, road and crash characteristics including with the experience of the driver. Logistic regression analysis was used fatal/non-fatal as crash fatality in dependent variable.	Light condition of the vehicle, type of road and type of crash, experience of driver, night time driving, pedestrian collision, speed driving and the impact of wrong direction driving were significantly associated with fatality risk of crash. Odds ratio of the analysis indicated that the drivers with less than 5 years driving experience showed significantly higher than the experienced drivers.

Researcher	Methodology	Findings
Demissie (2017)	Population bases study in Manzini City, Swaziland with RTAs occurrences from July 2013 to June 2015. The dependent variable was fatal and non-fatal (grievous, minor and property damage) accidents. Age, drink and drive, speed drive, gender as human characteristics, type of vehicle, mechanical faults of vehicle as vehicle characteristics, condition of road and lighting as infrastructural characteristics, weather condition and light condition as environmental characteristics were consider in this study. Multivariate logistic regression analysis was carried out in order to identify the risk factors associated with road accidents.	Occurrences of fatal RTAs, compared to non-fatal male drivers, drivers not wearing a seatbelt, pedestrian error, accidents occurring during weekends and accidents occurrences during 6.00 p.m. to 11.59 p.m. of the day have high risk.
Pino et al. (2014)	Study based on the total of 1498 RTAs occurrences in Parma, North Italy in year 2008. To determine the association between dependent (severe vs non-severe) and independent variables logistics regression analysis was used in this study. The independent variables of the study were accidents characteristics as vehicle, type, road surface, day of the week and time of the day, traffic density, weather and road condition, nationality, age and gender of the driver, cause of accident, injury, and death.	Results revealed that nigh hours are more risk in occur severe accidents than daytime, male drivers were more responsible for severe accidents than female drivers, weekends represent high rate of severe accidents. High speed driving, alcohol consumption of driver, have small proportion of cases in this study.
Mohammed (2013)	One year based time period on the RTAs in Ghana. To determine the risk factors associated with RTAs; logistic regression analysis was conduct. Fatal and non-fatal accidents were consider as the predictor variable and socio demographic characteristics of the driver, causes of RTAs, location characteristics of an accident and type	Time of the accidents occurred, location characteristics of an accident, gender of the driver and type of the vehicle were identify as the risk factors associated with RTAs in Ghana.

Researcher	Methodology	Findings
	of vehicles involving accident. Two logistic regression equations were carry out in this study. First equation was including with all the independent variables which were consider in the study and the second equation was excluding all the non-significant variables from the Wald's test.	
Mao et al. (1997)	Study was hospital based on case - control police observations in East-Central Canada. Demographic characteristics of injured person (age, sex, use of seat belts, speed limit, severity of the injury (fatal, major, minor, minimum), alcohol consumption rate, crash details as involved vehicles and maneuvers involved. Odds ratio was used to describe the risk factors associated with road accidents comparing fatal injury crashes.	Drinking and driving, impairment by alcohol, exceeding speed limits, errors by drivers as intersection without consider of bridges, tunnels and traffic control, unclear and bad weather condition, overtaking, full ejection from vehicle were identify as the risk factors of RTAs.

Based on the table 2.5, different characteristics were used in several studies in order to identify the risk factors associated with RTAs. They are, driver characteristics as age, gender, region, education, fatigue, experience, alcohol usage, nationality, driving under influence, seat belt usage; vehicle characteristics as brake problem, vehicle defects, type of vehicle; cause of accidents as speed driving, alcohol consumption, traffic density, overload; environmental characteristics as season, type of road, road classification, terrain, weather environmental factor (road surface, lighting condition, weather condition), location; time related characteristics as time, day, year, holiday. These characteristics are differ from study to study based on the research objectives, considered sample or population, collection method of data (if any study used primary data the questionnaires are differ from study to study and also if any study used secondary data the database consist in each countries are different) and considered time period. But all the studies have identified common risk factors associated with RTAs as speed driving, gender of the driver, not using seat belts and environmental characteristics. Additionally, Shakeer Kahn et al. (2017) have identified listening to music while driving; Rovsek et al. (2017) and Wang et al. (2017) have identified impact of wrong direction driving and Liu et al. (2018) have identified fatigue and overload as new risk factors associated with RTAs. Study done by Mao et al. (1997) have identified the different risk factors than the other scholars as mentioned in table 2.5; full ejection from vehicle, intersection without traffic control and bridge or tunnel. Furthermore, hospitals based studies (Mao et al., 1997; Shakeer Kahn et al., 2017) have highlighted that the alcohol consumption as the risk factor associated with RTAs. Five year based study done by Wang et al. (2017) in Wuhan city have identified most of the environmental related factors as the risk factors of RTAs.

Table 2.6, describes the risk factors of RTAs in Sri Lanka which are identified by Sri Lankan researchers.

Table 2. 6: Summary of Previous Research done in Sri Lanka

Researcher	Methodology	Findings
Amarasinghe and Dharmaratne (2019)	Cross sectional study with road accidents reported to 9 government hospitals in Kurunegala Police Division. Both primary and secondary data were used for this study from the period of April to December. The sample size of 851 RTAs. Environmental characteristics: type of the day (normal weekday, normal weekend, public holiday), time of the day (0.00 - 5.59, 6.00 - 11.59, 12.00 - 17.59, 18.00 - 23.59), Urban/Rural, light condition (day time light, night, with street lighting, nigh, without street lighting); road characteristics: type of road (minor roads, major roads), type of junction (no junction with 10m, junction, other); type of vehicle, age and gender of road users were considered as the variables of the study.	Among the road accidents reported from this period 8% were fatal accidents, 70% were non-fatal accidents and 22% were damage accidents. Most of the fatal accidents reported during 00.00 to 5.59 in rural areas and 12.00 to 17.59 in urban areas. The estimated average rate of occur fatal accident per day is 3. Motorcyclists' age from 31 to 40 were more vulnerable road users in this division. Pedestrians' collision were highly reported while crossing the road.

Researcher	Methodology	Findings
Dhananjaya and Alibuhtto (2016)	Yearly RTAs data from the period of 2010 - 2014 were consider for the analysis. 13 factors were considered as road surface (dry, wet, other), light condition (daylight, night, no street lighting, dusk/dawn, nigh, improper street lighting, night, good street lighting), location type (stretch of road no junction within 10m, 4 leg junction, T junction, other) , age of the driver (less than 18, 18 - 30, 30 - 40, 40 - 50, 50 - 60, more than 60), validity of license, alcohol test, accident causes (speeding, aggressive/ negligent driving, influence by alcohol/ drugs, fatigue / fall asleep, other), urban/ rural, workday / holiday, weather (clear, cloudy, rain, other), vehicle type (car, dual purpose vehicle, lorry, motorcycle/moped, three wheeler, SLTB bus, private bus, other), vehicle ownership (private vehicle, government vehicle, other) and age of vehicle (less than 10 years, 10 - 20, 20 - 30, more than 30 years). Binomial Logistic Regression analysis was used as the dichotomous dependent variable (fatal/non-fatal).	According to the results, sector (urban/rural), weather condition, type of vehicle, light condition of the road, age of the vehicle and driver, validity of the licenses have a decreasing effect on the probability of occur fatal accident. And alcohol test of driver, causes of accident, type of location have an increasing effect on occur fatal accidents. Among the variables which have increasing effect on the fatal accidents causes of accidents is the most influential variable.
Renuraj et al. (2015)	692 road accidents reported from 2010 - 2013 to the Jaffa Police Satiation were consider in this study. Dependent variable is severity of accident (fatal/non-fatal). Study used logistics regression approach for the analysis to identify the risk factors of RTAs.	Results indicated that time, location, type of vehicle, gender, license status, cause of accident, type of accident, type of vehicle and age were identified as more influential variables for the accident severity. Causes of accidents as collision with vehicles, animal/pedestrian, fixed object, other types are found as most influencing factors on the accident severity in Jaffna.

Researcher	Methodology	Findings
Chinthanie (2015)	Southern Expressway in Sri Lanka during the period of 2011 - 2013 was the study area. Human factor: speed, suddenly stopping, incompetent driving, overtaking, negligence, fatigue; vehicle factor: vehicle condition (technical problems, firing); road environmental factors: road (road surface, road geometry), weather, animal factor, stone fallen considered as the variables. Descriptive statistics techniques were used for the data analysis.	Speed driving, poor road environment under rainy weather (slippery road condition), driver fatigue were the risk factors of RTAs in southern expressway. Study revealed that night time accidents are twice higher than daytime accidents.
Nandana (2015)	Study involved the data in police divisions in 2013 and 2014 for a selected week. Detail analysis of accidents were done by through examination of all elements contributing to the accident which describe the event of crash, injury mechanism and the contribution factors as location, date and time, involved parties, number of injuries, accident case, statement of witnesses, collision type, vehicle data, road type and condition, weather and visibility, sketch of the accident situation. The contribution principle factors are human factors (negligence, pedestrian in road, impairment of alcohol and drugs), vehicle factors (vehicle defects), road/environment factors (road condition, road environment)	Human factor was the leading contributory factor for RTAs. Visibility, geometry, lane markings, surface condition, street lighting facility, weather have potential influence on the drivers.
Jeepara and Pirasath (2011)	Study based on Teaching Hospital, Batticaloa during the period 1st April to 31st June 2010. Questionnaire were given to all patients admitted with road traffic injuries to the single surgical unit. Descriptive Statistics techniques were used for the data analysis.	Male drivers' age between 19 to 40 years old are considered as more vulnerable road users in urban areas. Alcohol consumption, driving without valid license, without wearing helmets were the risk factors identified in this study.

Among the six mentioned studies in the table 2.6, only two studies (Dhananjaya & Alibuhtto, 2016; Nandana, 2015) have focused on road accidents in the entire country, while other studies are focused on one area or one location (Amarasinghe & Dharmaratne, 2019; Renuraj et al., 2015; Chinthanie, 2015; Jeepara & Pirasath, 2011). Two studies (Dhananjaya & Alibuhtto, 2016; Renuraj et al., 2015) have absorbed on the fatal and non-fatal accident's behavior; both studies claimed that type of the vehicle and age of the driver have high influence on the fatal RTAs. Additionally, Dhananjaya and Alibuhtto (2016), Nandana (2015) and Chinthanie (2015) have identified that light condition, weather and geographical features of the road were high influencing factors of RTAs in Sri Lanka. Male drivers age between 19 - 40 and pedestrians are more vulnerable than other road users. Furthermore, when advertence to the variables considered in each studies mentioned in table 2.6, probably the same variable has been considered except the study done by Jeepara and Pirasath (2011).

When comparing the findings of Sri Lankan studies with foreign studies (Table 2.5 & 2.6), speed driving, alcohol usage, road characteristics, weather characteristics and fatigue can be recognized as the common key factors which are influencing for RTAs. Additionally, nighttime accidents are more prevalent than the day time accidents and pedestrians are most perilous road users from road accidents. However, there is no attentive on the accidents due to not using seat belts in studies done in Sri Lanka. Furthermore, all the studies based on the hospitals, identified alcohol consumption as the risk factor of RTAs. Thus, on the view of the above explanations it can be conclude that some risk factors are similar for all the studies while some are differing from study to study.

In addition to the above studies, some reports also have highlighted the risk factors of RTAs. Errors made by those behind the wheel, poor conditions of roads, errors made by foot-travelers, poor vehicle conditions were stated as the most typical causes of RTAs in a report on Road safety done in India (WHO, 2010). The actions of those who use the road was singled out as the most influencing factor for RTA fatalities reported in Ireland. It was found that actions of the drivers, actions of foot-travelers, factors related to roads, environmental and vehicle factors contribute 88%, 8%, 2% and 2% respectively to road fatalities (Mayo Road Safety, 2005). Behavior of drivers and pedestrians, vehicle defects and road and environmental factors were recognized as key influencers of RTAs in a report from the United Kingdom (Annual Report GB, 2011).

Additionally, WHO (2009) announced common influencing causes of RTAs as,

I. Elements that influence exposure to risk (social deprivation, age and sex)

This involves economic factors such as deprivation from society, demographic elements, duration of a trip and mode of travel, grouping of high-speed automobile traffic with vulnerable road users, road layout and design and insufficient attention that is given to the assimilation of road function with decisions related to speed-limit.

II. Risk factors influencing crash involvement (young male, fatigue inadequate visibility)

Excessively surpassing the speed limit, drunk driving and presence of alcohol, driving under the influence of medicinal and recreational drugs, exhaustion, being a young male, being a vulnerable user of roads in a residential or urban landscape, travelling after dark, vehicle related factors such as braking, maintenance, poor road design prompt unsafe road user behavior and insufficient visibility according to the crash involvement WHO (2009).

III. Factors that influence the severity of a crash (not wearing safety equipment, excessive speed alcohol)

Tolerance levels of human beings, high-speed driving, neglecting the use of safety helmets, seat belts and child restraints, objects on the roadside that are not crash protective, inadequate availability of automobile crash protection for riders and for other who fall victim to crashes, alcohol and drug presence are considered as elements that affect severity of crashes.

IV. Severity of injuries after road traffic crash (delay in detecting crash, and transportation)

Late detection of crashes, eruption of fire as a result of collisions, alcohol and drug presence, leakages of dangerous liquids and material, struggles faced when extracting people from the crashed vehicle, struggles in removing people from crashed coaches and busses, lack of appropriate pre-hospital care and inadequate care given in hospital emergency wards.

Moreover, WHO (2016) and WHO (2018a) declared that speed, drunk driving, not wearing helmets, not using seat belts and child restraints as the risk factors of RTAs in South Asian Region as well as globally based on the road accidents statistics of countries. They state that establishing laws to minimize these risk factors are an important element in integrated strategies to prevent the loss of lives caused by RTAs. Therefore, identifying the risk factors of RTAs is a vital topic for countries for their decision making process, to update the road rules, to set new road rules, as these risk factors are prone to change from time to time.

2.5. Modeling of Risk Factors Associated with RTAs

Several statistical methodologies have been employed by number of prominent scholars to identify the risk factors associated with RTAs (Chang & Yeh, 2006; Al-Ghamdi, 2002; Dissanayake, 2004; Johnson & Walker, 1996). According to the table 2.5 and 2.6, studies done by Nasiri et al. (2019), Wang et al. (2017), Demissie (2017), Pino et al. (2014), Mohammed (2013), Dhananjaya and Alibuhtto (2016) and Renuraj et al. (2015) have used logistic regression analysis to identify the risk factors associated with RTAs.

Nasiri et al. (2019) defined the type of incident as a two-way dependent variable, with the code number 1 assigned to death and 0 to injuries. Variables, such as the type of accidents, drivers' level of education, season, type of road, cause of accident, year of accident, and occurrence on a holiday or other days were all considered as independent variables. Their study used the multivariate logistic regression analysis to perform for the variables with the p-values lower than or equal to 0.25 in the univariate analysis and in each steps. Variables with the highest significance levels were eliminated from the model using the backward elimination method. The final model was selected with the highest values for the AIC (Akaike Information Criterion) and the BIC (Bayesian Information Criterion).

Study of Wang et al. (2017) were used univariate and multivariate logistic regression analysis to identify the risk factors of crash fatality. The matched Odd Ratio (OR) was used to estimate the influence of different risk factors on response with 95% confidence intervals.

Demissie (2017) was applied binary logistic regression to identify the relationship between dependent (fatal/non-fatal RTA) and independent variables. The dependent variable was categorized as the grievous, minor and property damage of RTAs as the non-fatal RTAs. Variables which are found to have p-values of ≤ 0.05 were further assessed employing multivariable logistic regression analysis. Adjusted OR was computed and variables that showed p-values ≤ 0.05 in the multiple logistic regression models were considered significantly associated with the dependent variable.

Study done by Pino et al. (2014) used multivariate logistic regression analysis to identify the risk factors associated with RTAs and OR to estimate the likelihood of occur fatal vs non-fatal accidents. The OR is the estimates of relative risk of people being injured given that they have been involved in an accident. The model was tested against the global null hypothesis using the log likelihood ratio test.

Study done by Mohammed (2013) also used logistic regression analysis in his study to predict the relative likelihood of being died in a road accident. In this study, code $y = 1$ (non-fatal) and $y = 0$ (fatal). The analysis began by testing the significance of the association each explanatory variable could have with the dependent variable. For this purpose the entering selection process of logistic regression was followed in this study.

From the analysis of the logit model, there were two variables are not significant, thus another model was fitted by excluding these variables.

Additionally, to the above mentioned studies done is different countries, as mentioned in the table 2.5, two studies done in Sri Lanka have also used logistic regression analysis to identify the risk factors associated with RTAs. Among them Dhananjaya and Alibuhtto (2016) did their data analysis mainly under preliminary and fundamental analysis. In preliminary analysis included univariate analysis and bivariate analysis. Univariate analysis is performed to get a general understanding of the whole dataset and bivariate analysis is functioned to examine the relationships between the variables. Due to the dichotomous nature of the dependent variable (fatal/ non-fatal), this study carried out a binary logistic regression analysis as fundamental analysis to investigate the combined effect of the variables. For developing the binary logistic model, study used the Backward Elimination (Likelihood Ratio) method. All variables were entered into the analysis and by extracting insignificant ones, model iteration occurred up to four steps. The analysis was performed on p-value = 0.05 significance level to formulate the model.

Renuraj et al. (2015) were used the nature of accident (0 represents the accidents which result no fatality but at least have one injury, 1 represents the accidents which result at least one fatality) is taken as a response variable. Since the response variable is dichotomous, the logistic regression model is used to fit the data. To estimate the parameters of the logistic regression model, study used the maximum likelihood procedure.

Liu et al. (2018) first used a preliminary review of scatter plots to identify which variables indicated that the potential association may not be linear. Because of the outcome variable was a continuous variable (the number of extremely serious road accidents in each month), they deliberated on the options of poisson regression model, zero-inflated regression model, and negative binomial regression model. Due to the over dispersion, the negative binomial regression model without zero inflation adjustment was selected. Univariate negative binomial regression analysis was done first. Then, negative binomial regression analysis with ten variables was conducted to explore the factors associated with increased risks of extremely serious road accidents. After that, further analysis was developed using the subgroup data which was arranged according to the different regions where the extremely serious road accidents occurred. The Variance Inflation Factors (VIFs) among independent variables were calculated in order to diagnose the multicollinearity.

Furthermore, according to the above mentioned researches, logistic regression has been considered as an appropriate method of identify the risk factors associated with the RTAs. Not only had these studies but also studies done by Dissanayake (2004), Liu and Dissanayake (2009), Johnson and Walker (1996) and Rodgers (1997) also used logistic regression analysis for their studies on RTAs.

2.6. Summary of the Chapter Two

Based on past work carried out by various researchers in different countries, RTAs can be classified as a prominent community well-being problem on a global level, resulting in deaths and disabilities generating grief for those who suffer from RTAs and their families and damaged property as well as vehicles. The factors influencing on RTAs used vary from time to time, even within a country. In Sri Lanka, the last study has been reported in 2019, but it is a hospital based study in Kurunegala Districts. Study of RTAs in the whole country has been reported in 2016; by focusing on the RTAs during the period from 2010 - 2014. Thus, it is important to analyze most recent data to identify the risk factors associated with RTAs in Sri Lanka.

CHAPTER 03

MATERIALS AND METHODS

This chapter explains data (materials), data collection methods, preliminary data verification, research framework and statistical analysis used in the research to achieve the objectives.

3.1. Secondary Data

This study consists with panel data of RTAs in Sri Lanka which were gathered from the Sri Lanka Police. All the data are extent the period of 2005 - 2019. The variables of the study can be explain based on the three sections according to the three objectives. Figure 3.1, have clearly described the variables of the study based on the three objectives.

As specified in chapter one (Section 1.4), Sri Lanka Police have identified several causes of RTAs and categorized those causes into 7 sections as, accidents due to overtaking, accidents due to speed driving, accidents during diversion, alcohol consumption of driver, accidents due to mechanical faults, negligence of pedestrians, and other reasons. Among these 7 causes factor analysis will be carried out to identify the key factors of RTAs in Sri Lanka during the period of 2005 - 2019.

Additionally, study conducted by Dhananjaya and Alibuhtto (2016), used 13 attributes to determine the risk factors associated with RTAs. However, in addition to those attributes, two other attributes were included; type of week as time and environmental characteristics and gender of driver as human and accident characteristics. As shown in figure 3.1, total of 15 attributes were used to identify the risk factors associated with RTAs. Key factors of RTAs which will be identified in the second objective also consider as an attribute in this section to achieve the third objective.

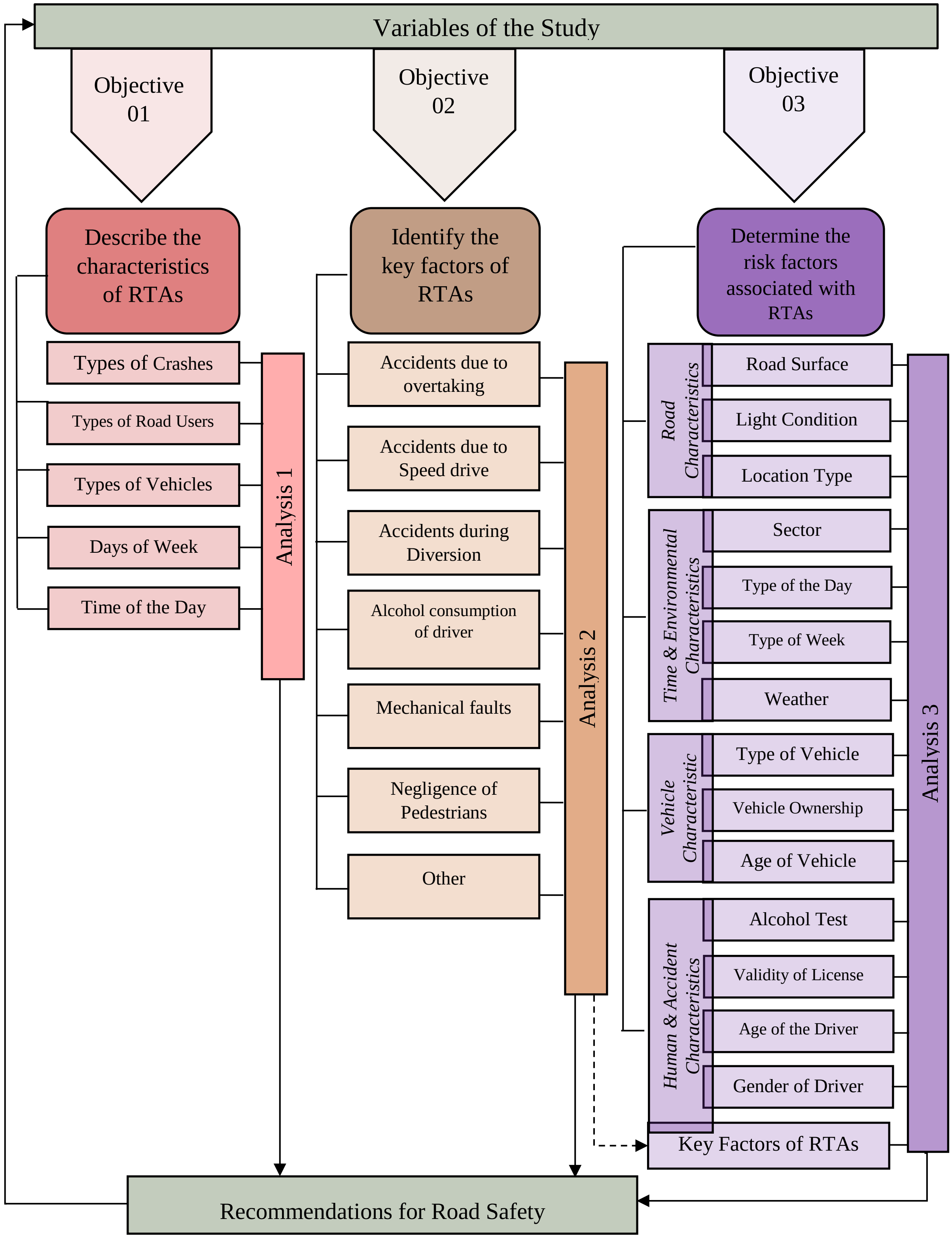

Figure 3. 1: Variables of the Study

3.5. Statistical Analysis

Descriptive statistics, data presentation methods, correlation analysis and chi-square test will be used to achieve the first objective of this study. Explanatory Factor Analysis (EFA) will be used to determine the key factors of RTAs and Confirmatory Factor Analysis (CFA) will be used to further evidence regarding the key factors of the suggested model with regard to the factors identified by EFA. And binary logistic regression analysis will be used to determine the risk factors associated with RTAs.

3.5.1. Descriptive Statistics

Descriptive statistics techniques allow to describe, display or summarize data in a meaningful way by identifying the distribution, central tendency and dispersion of the data. Distribution helps to summarize the frequency of individual values, central tendency is describing the central position of a frequency distribution and dispersion is describing how spread out the scores are. This analysis will use mean as the central tendency measurement and variance as the dispersion measurement to describe the behaviour of RTAs during the period of 2005 - 2019.

3.5.2. Data Presentation Techniques

To identify the trend of the RTAs during the period of 2005 - 2019, this study will use line charts as the data presentation technique. Line chart is the best method when observe the values of a variable at different time period. It show data variables and trends very clearly and can assistance to make predictions.

3.5.3. Correlation Analysis

Correlation of coefficient allows to identify the relationship between two quantitative variables. The value of this statistic ranges $-1.0 \leq r \geq +1.0$. Arora et al. (2007) mentioned that there are 12 types of correlation; positive correlation, negative correlation, linear correlation, perfectly linear correlation, direct or perfect positive correlation, inverse or perfect negative correlation, high degree positive correlation, high degree negative correlation, low degree positive or negative correlation, no correlation and curvilinear correlation. Furthermore, Arora et al. (2007) mentioned, scatter or dot diagram method, Karl Perason's Coefficient of correlation, Spearman's Rank correlation, Two-way frequency table and concurrent deviation method as the 5 methods to study correlation between variables. This study will use Karl Perason's Coefficient of correlation to check whether there is any significant relationship between the number of accident occurred by types of vehicles and their population during the period of 2005 - 2019. It is the best method to measures the statistical relationship, or association, between two continuous variables.

$$r = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2 \sum(y-\bar{y})^2}} \tag{3.1}$$

3.5.4. Chi-Square Test Statistic

Chi-square statistic (χ^2) is best method to test the association between categorical variables. The importance uses of this test statistic is, test of goodness of fit, test of independence of attributes and test of homogeneity (Arora et al., 2007). This test is commonly used to test the independence (association) between variables.

H_0: No Association exists between the attributes

H_1: An association exists between the attributes

$$\chi^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i} \tag{3.2}$$

O_i - Observed value of ith event

E_i - Expected value of ith event

3.5.5. Factor Analysis (FA)

Factor analysis is a statistical data mining technique. It determines whether the set of observed covariance and/or correlation structure among the observed variables can be explained in terms of smaller number of unobservable factors. This is known as latent factors (Peiris, 2018). Two techniques are used in this method of analysis; EFA and the CFA.

3.5.5.1. Explanatory Factor Analysis (EFA)

The principal procedure of EFA is to check whether the data is suitable for factor analysis. EFA used to reduce the amount of data to be used in subsequent analyses or determining the number and character of underlying factors (latent) in a data set (Plucker, 2003). There are many methods,

i. Correlation Matrix of the observed variables

To conduct the factor analysis it is required to have high significant correlation among variables. This can be check though the Bartlett test where $H_0: \sum = 1$ vs $H_1: \sum \neq 1$. The null hypothesis should be rejected to have the significant correlation among variables.

ii. Kaiser-Mayer-Olkin (KMO) Statistic

KMO statistic measure the sample adequacy which compares the correlation coefficients and partial correlation coefficients. KMO statistic is used test the suitability of factor analysis for the considered data set. If this statistic closer to 1, indicates that the factor analysis is better to conduct. Thus, the cut-off value is > 0.6 in order to carry out factor analysis.

iii. Chronbach's Alpha Statistic

This statistic mainly uses for categorical data to check the internal consistency of data. If the similar results produces under consistence conditions, the measure have high reliability.

The minimum value of this statistic should have 0.8. Thus the general rule of thumb is; Chronbach's alpha value ≥ 0.7 (Peiris, 2018).

iv. Normality of the variables

The normality of the variables can be derive through the Anderson-Darlington test (AD test) or Q-Q Plot. When all the variables are normally distributed then it is suggested that to use Maximum Likelihood extraction method for the factor extraction method. However, FA analysis is heavily used for categorical data where normality assumption is not satisfied (Peiris, 2018).

3.5.5.2. Confirmatory Factor Analysis (CFA)

CFA have facility to correlate each of errors, and check whether the model is equal across the data from separate groups (Plucker, 2003). CFA is used to test the researcher's prior theoretical arrangement of factor loadings based on the pre-decided factors.

The commonly reported fit indices of CFA are as follows,

i. Model Chi-Square

Chi-square test allows to test the difference in covariance matrices. The test statistic can be define as,

$$\chi^2 = (n-1) \times (S - \Sigma_k) \quad (3.3)$$

S - Observed covariance matrix

Σ_k - Estimated covariance matrix

n - Sample size

H_0: No significant differences between observed and estimated covariance matrix

H_1: Significant differences between observed and estimated covariance matrix

ii. Root Mean Square Error of Approximation (RMSEA)

RMSEA examines the difference between actual and predicted covariance (Byrne, 1998). If the range of this statistic distributed 0.05 - 0.10; indicates fair fit and RMSEA value is greater than 0.10 indicates poor fit. A value of 0.08 or less is desirable. Value between 0.08 - 0.10 indicates moderate fit (Hu & Bentler, 1999).

$$RMSEA = \sqrt{\frac{\chi^2/(df-1)}{(n-1)}} \quad (3.4)$$

iii. Root Mean Square Residual (RMSR) and Standardized Root Mean Square Residual (SRMR)

RMSR is the square root of the mean of the squared residuals and SRMR is the standardized value of RMSR. Kline (2005) mentioned that RMSR is difficult to interpret as the results of this statistic contains varying levels. Thus, SRMR is better to use instead of RMSR. The value of SRMR varying between 0 - 1.0; value of 0.08 or less is desirable (Diamantopoulos & Siguaw, 2000).

iv. Normed Fit Index (NFI) and Non-normed Fit Index (NNFI)

NFI indicates the difference of the χ^2 value of the proposed model and null model. Value of the ranges between 0 - 1; more than 0.9 indicate good fit (Bentler & Bonnet, 1980). Due to the major limitation of the NFT; as it is more sensitive to the sample size NNFI is used to determine the model fit. This statistic also knows as Tucker-Lewis index - TLI. Bentler and Bonnet (1980) have mentioned NNFI $\geq$ 0.95 as the threshold.

v. Comparative Fit Index (CFI)

The CFI is improved version of NFI. This index performs well when the sample size is small (Byrne, 1998). CFI value ranges 0.0 - 1.10; 0.90 and above is considered good fit.

vi. Goodness of Fit Index (GFI)

GFI check whether the model is able to replicating the observed covariance matrix. The possible range of this statistic is 0 to 1. GFI value 0.9 and above is considered as more appropriate.

vii. Adjusted Goodness of Fit Index (AGFI)

Possible range of AGFI is also 0 to 1. This statistic accounts for the degree of freedom. Generally, value 0.9 or greater indicate good fitting models.

viii. Parsimony Fit Indices

There are two forms of parsimony indices. The first form is Parsimonious Goodness of Fit Index (PGFI) and Parsimonious Normal Fit Index (PNFI). The second form is “information criteria” indices; such as AIC or the Consistent Version of AIC (CAIC). Mulaik et al. (1989) mentioned that it is difficult to give the threshold for PGFI and PNFI. But Mulaik et al. (1989) recommended within the 0.50 region if preferable.

3.5.6. Extraction of Factors

There are many methods for factors extraction; such as Principle Component Factoring (PCF), Principle Axis Factoring (PAF), Maximum Likelihood Factoring (MLF). However, PCF is the most popular method of factor extraction. Furthermore, when all the variables considered are normally distributed, MLF method can be used for factor extraction.

3.5.6.1. Principle Component Factoring (PCF)

In PCF it is assumed that the communalities for all the variables are equal to one and consequently no prior estimates are required for communalities. And that few principle components; components which are eigenvalue is greater than 1 would account for a majority of the observed variance of the system. They are considered as factors (Peiris, 2018).

3.5.6.2. Principle Axis Factoring (PAF)

The PAF an attempt is made to estimate the communalities. These communalities play a main role in extracting factors. The estimation of mutual variance is; communalities are less than 1. PAF use reduces correlation matrix which is replacing the 1 with the communalities of observed variables. After replacing the main diagonal of the correlation matrix, then calculate the new communalities by using eigenvalues and factor loadings. This process is continue by updating the correlation matrix until the communalities are not change much. This means that, the process is continue until the difference between two consecutive communalities reached very small point.

3.5.6.3. Maximum Likelihood Factoring (MLF)

If all the considered variables are normally distributed then MLF can be apply. This method provides a limited range of goodness of fit test and does allow for the statistical hypothesis testing. MLF assumed that the data are derived from multivariate normal, thus the hypothesis can be derived as

H_0: q factors are sufficient

H_1: More factors are needed.

Under the H_0 the test statistic is distributed chi-square with degrees of freedom of

$$\frac{(p-m)^2-(p-m)}{2} \tag{3.5}$$

3.5.7. Binary Logistic Regression Model

The binary logistic regression analysis is used in this study to predict the relative likelihood of happen fatal RTAs against the non-fatal RTAs in order to determine the risk factors associated with RTAs in Sri Lanka.

The goal of using the binary logistic regression in this study to describe the association between accident severity (fatal/non-fatal) and explanatory variables which describe the road, human, vehicle, accident, time and environmental characteristics of RTAs by identifying the best fitted model. Mohammed (2013) claimed that, parameters obtained from the each explanatory variables in the model is used to estimate the odds ratio. The dependent variable (y) denotes its binary category as 1 and 0. This study code y = 1 (fatal accidents) and y = 0 (non-fatal accidents).

The specific form of the logistic regression model can be define as:

$$\pi\ (x) = p = \frac{e^{\beta_0 + \sum_{i=1}^{n} \beta_i x_i}}{1+e^{\sum_{i=1}^{n} \beta_i x_i}} \qquad (3.6)$$

The logit transformation of the odds dependent variable is 1; from 3.4,

$$logit\ (p) = ln\left(\frac{p}{1-p}\right) = \beta_0 + \sum_{i=1}^{n} \beta_i x_i \qquad (3.7)$$

Where

β_0 - Model constant

β_i - Parameter estimates for independent variables

x_i - Independent variables ($i = 1,2, \dots \dots n$)

p - Probability ranges from 0 to 1

$ln\left(\frac{p}{1-p}\right)$: The natural logarithm ranges $-\infty$ to + ∞

The P(Y) is predicted given by, when there is only on independent variable

$$P\ (Y) = \frac{1}{1+e^{-(b_0 + b_1 X_{1i})}} \tag{3.8}$$

P(Y) - Probability of occurring Y

e - Base of natural logarithms

b_0 - Coefficient of the constant

b_1 - Coefficient for the

3.5.7.1. Log - Likelihood Statistic

The log-likelihood statistic is calculated by,

$$log - likelihood = \sum_{i=1}^{N} [Y_i \ln(P(Y_i)) + (1 - Y_i) \ln(1 - P(Y_i))] \tag{3.9}$$

This statistic indicates the unexplained information remain in the model after the model has been fitted. The large value of the log-likelihood statistic indicates the poor fitting and more unexplained observations (Field, 2009).

3.5.7.2. Cox & Snell Pseudo R^2 and Nagelkerke Pseudo R^2

Both Cox & Snell R^2 and Nagelkerke R^2 indicate that the percentage of variance of dependent variable explained by the model.

$$\text{Cox \& Snell Pseudo } R^2 = 1 - \left[\frac{-2LL_{null}}{-2LL_k}\right]^{\frac{2}{n}} \tag{3.10}$$

Nagelkerke R^2 is used to revise if the Cox & Snell R^2 value reached 1.

$$\text{Nagelkerke Pseudo } R^2 = \frac{1 - \left[\frac{-2LL_{null}}{-2LL_k}\right]^{\frac{2}{n}}}{1 - (-2LL_{null})^{\frac{2}{n}}} \tag{3.11}$$

3.5.7.3. Hosmer Lemeshow Test

This statistic is used to check the goodness of fit of the logistic model. It measures whether the observed data match with the expected data which are computed under hypothetical model. This is also a lack of fit statistics and the equation is given by,

$$H = \sum_{g=1}^{n} \frac{(O_g - E_g)^2}{N_g \pi_g \,(1 - \pi_g)} \tag{3.12}$$

3.5.7.4. Wald Statistic

This statistic also called as Wald Chi-square test which used to determine the explanatory variables of the model are significant.

It follows a standard normal distribution with the null hypothesis that $\beta_1 = 0$. The formula is given by,

$$W = \frac{\hat{\beta}_1}{SE\,(\hat{\beta}_1)} \tag{3.13}$$

Where,
$\hat{\beta}_1$- Estimated value of the parameter
$SE\,(\hat{\beta}_1)$ - Standard error of estimated parameter

3.5.7.5. Odds Ratio (OR)

The OR or Exp (B) is an indicator of, when the change in odds resulting from one unit of predictor variable change.

The equation of the odds ratio can be written as,

$$odds = \frac{P(event)}{P(no\ event)} \tag{3.14}$$

Calculate first set of odds using equation 3.6.

$$P(event\ Y) = \frac{1}{1 + e^{-(b_0 + b_1 X_1)}} \tag{3.15}$$

$$P(no\ event\ Y) = 1 - P(event\ Y)$$

When the predictor variable/variables has changes by 1 unit, the value of X = 1. To calculate the proportion of change in odds define as,

$$\Delta odds = \frac{odds\ after\ a\ unit\ change\ in\ the\ predictor}{original\ odds} \tag{3.16}$$

$\Delta odds$ is define as OR or Exp(B), and can use to interpret the change in odds. If this odds ratio value is greater than 1, then it indicates as the predictor increase. OR value is less than 1, indicates as the predictor decreases (Field, 2009).

CHAPTER 04

CHARACTERISTICS OF THE ROAD TRAFFIC ACCIDENTS (RTAs) IN SRI LANKA

This chapter describes the characteristics of the RTAs in Sri Lanka during the period of 2005 - 2019. The characteristics considered are: types of crashes, types of road users, types of vehicles, days of the week and time of the day.

4.1. Annual Trend in RTAs and Comparison among Three Scenarios

In terms of road accidents in Sri Lanka over the last 15 years, there can be seen considerable changes in different periods as described in section 2.3. Thus, the entire time period from 2005 to 2019 was considered as three main scenarios based on the fatcs described in section 2.3 as shown in figure 4.1. Scenario I describes the period from 2005 - 2008, scenario II describes the period from 2009 - 2012 and scenario III describes the period from 2013 - 2019.

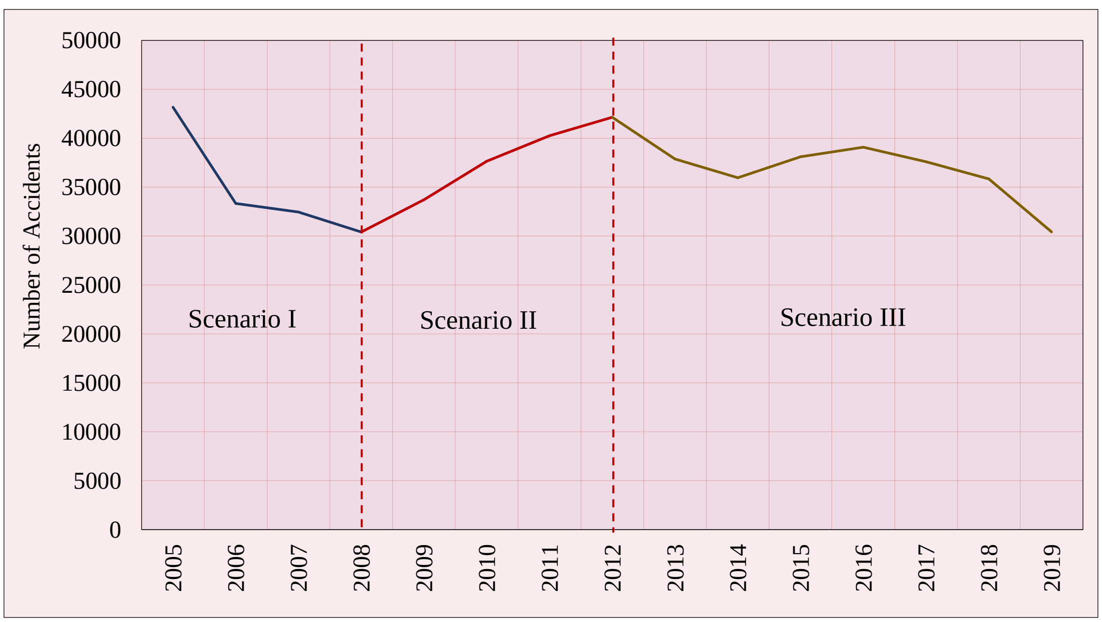

Figure 4. 1: RTAs in Sri Lanka (2005 - 2019)

During the period from 2005 to 2019, the number of total accidents has varied from minimum 30,420 to maximum 43,171 with a mean of 36,539 and SE of mean 1,006. When examining to the behaviour of RTAs during this period; damage accidents represent the highest percentage compared to fatal, grievous and minor accidents (Table 4.1).

Table 4. 1: Basic Statistics of Each Scenarios by Types of Accidents

Type of Accident	Scenario I		Scenario II		Scenario III	
	Mean	SE of Mean	Mean	SE of Mean	Mean	SE of Mean
Fatal	2,135	24.3	2,405	81.2	2,640	121
Grievous	4,919	71.7	6,424	413	7,922	281
Minor	12,430	661	12,908	724	12,918	472
Damage	15,363	2,186	16,708	687	12,937	706

According to the table 4.1, of the three scenarios; most of the fatal, grievous and minor accidents have occurred during the period of 2013 - 2019 (Scenario III). Moreover, the SE of mean of both grievous and minor accidents are higher in second scenario and SE of mean of fatal accidents are higher in third scenario. Additionally, damage accidents are highly reported during the period of 2009 - 2012 (Scenario II), but the SE of mean are high during the period of 2005 - 2008 (Scenario I).

As shown in figure 4.2, fatal and grievous accidents represent an increasing trend when moving from each scenarios. But minor and damage accidents show an opposite trend from fatal and grievous accidents. It designates that there is a continuous decrease in damage road accidents and in minor accidents; scenario II represent the lowest rate in comparison to the other two scenarios. As described in section 2.3, this trend can be due to the under reporting of the RTAs. Thus, to acquire reliable indication of the RTAs in Sri Lanka it is vital to consider the behaviour of the fatal and grievous road accidents. Figure 4.3 indicates the trend of fatal and grievous RTAs in Sri Lanka from 2005 - 2019. It can be seen that both types of road accidents demonstrate an increasing trend during this period.

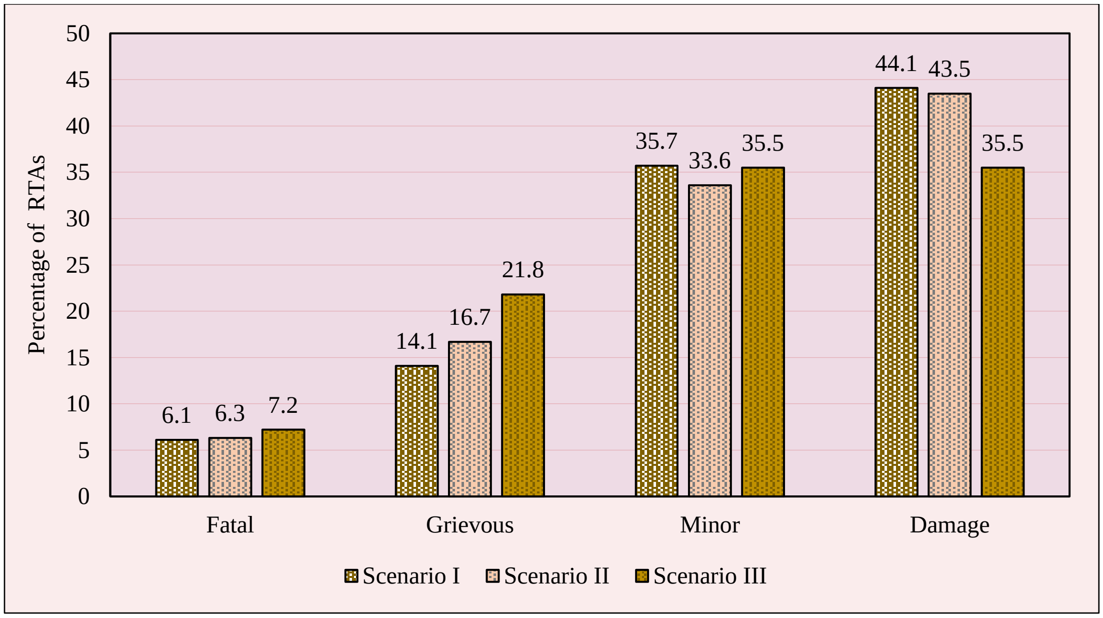

Figure 4. 2: Contributing Percentage of Types of RTAs in each Scenarios

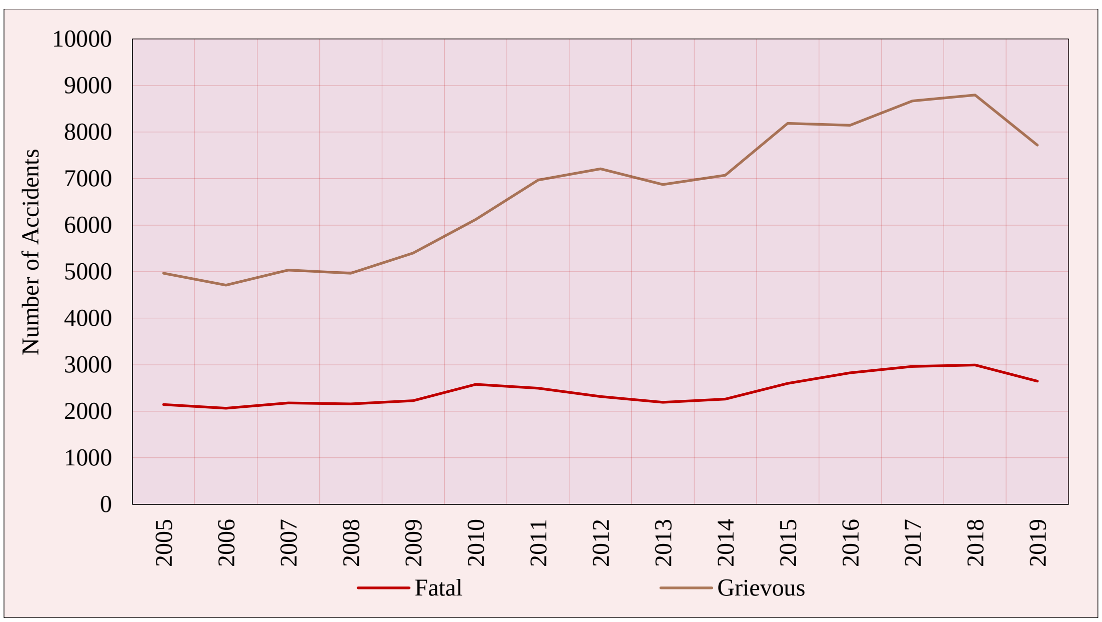

Figure 4. 3: Annual Trend in Fatal & Grievous RTAs in Sri Lanka (2005 - 2019)

In fact, the fitted liner trend line for both variables were statistically significant and the fitted trend lines for the fatal and grievous road accidents were able to explain 66% and 89% of the observed variability respectively as corresponding R^2 were .66 and .89. Thus it can be concluded that based on the gradient of the fitted linear models, the fatal road accidents are increased on average at a rate of 57 per year and grievous RTAs are increased on average at the rate of 303 per year.

4.2. Vulnerable Road Users

When observing number of deaths due to RTAs in Sri Lanka during the period from 2005 to 2019, pedestrians and motorcyclist represented the highest rate; 29% and 27% of all deaths due to the RTAs respectively. Furthermore, back-riders, drivers and cyclists represented the nearly 10% of the all deaths and passengers represented 16% of all deaths during the considered period of this study[6]. Thus it can be concluded that pedestrians and motorcyclists were more vulnerable road users in Sri Lanka during the period of 2005 to 2019.

Table 4. 2: Died Road Users in Each Scenarios

Type of Accident	Scenario I		Scenario II		Scenario III	
	Mean	%	Mean	%	Mean	%
Pedestrians	670	29.3	765	29.9	828	29.3
Motorcyclist	492	21.6	658	25.7	878	31.1
Back-riders	157	6.9	190	7.4	197	7.0
Cyclists	285	12.5	271	10.6	248	8.8
Drivers	216	9.5	228	8.9	227	8
Passengers	370	16.2	395	15.4	436	15.4
Other	93	4.1	54	2.1	9	0.3
Total	2,283		2,559		2,824	

As the most vulnerable road users, deaths of both pedestrians and motorcyclists have an increasing trend when moving from scenario I to II and III. But deaths of motorcyclists

[6] During the period from 2005 - 2019; Total deaths by RTAs = 39,133. Among them Pedestrians = 11,537, Motorcyclists = 10,749, Back-riders = 2,764, Cyclists = 3,957, Drivers = 3,365, Passengers = 6,109 and Other road users = 652

show a rapidly increasing trend than pedestrians. All other road users mentioned in table 4.2, have a decreasing trend and there is a discernable decrease of cyclist's deaths due to RTAs. When advertence to the increasing percentage of the pedestrians and motorcyclists in table 4.2, it can be concluded that motorcyclists are the utmost vulnerable road users for the foreseeable future. This situation is challenging to control because the motorcycle population in Sri Lanka is very high in number compared to other types of vehicles (Figure 4.5). Figure 4.4 indicated that the motorcycle population make up more than half of Sri Lanka's total automobile population while car and three-wheel population represent the 2nd and 3rd highest population respectively.

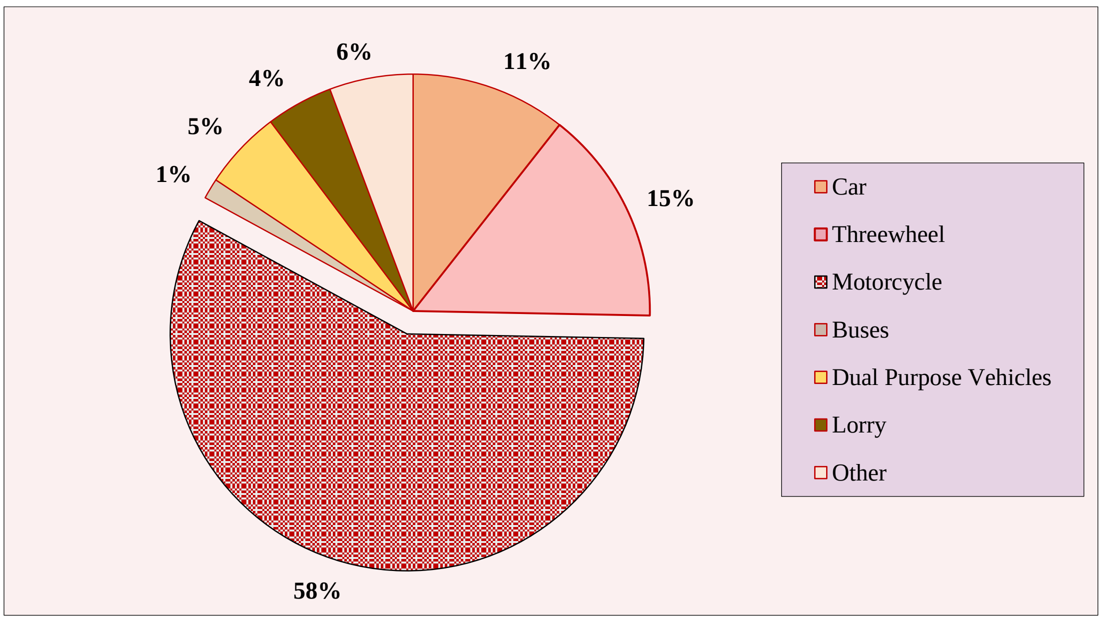

Figure 4. 4: Automobile Population in Sri Lanka (30th November 2019)

4.3. RTAs by Types of Vehicles

The number of RTAs and the amount of injured people as well as lost lives, and the amount of vehicles involved have rapidly risen in Sri Lanka. In fact, according to the table 4.3, there is significant positive or negative correlation ($p < 0.05$) between the number of accidents and the number of each types of vehicle except lorries.

Table 4. 3: Correlation Coefficient between Automobile Population and Number of Accidents in Each Types of Vehicles (2005 - 2019)

Type of Vehicle	Correlation Value	Sig. Value
Motorcycle	0.777	0.001
Car	0.637	0.011
Three-wheel	0.664	0.007
Dual Purpose Vehicle	- 0.750	0.001
Lorry	- 0.413	0.126
Bus	- 0.875	0.000

It indicates that even though the population of large vehicles (lorries, buses and dual purpose vehicles) have risen over the years, the number of accidents due to those vehicles have not been increased. However, the number of accidents involving motorcycle, car and three-wheels have the positive correlation with population of those vehicles while dual purpose vehicle and bus have the negative correlation.

The behaviour of the road accidents involving vehicles, based on the types of accidents among the three scenarios are show in table 4.4. Motorcycle involved in fatal, grievous, minor and damage accidents show an increasing trend when moving from scenario I to II and III. A similar trend can be seen in three-wheel and car involved in fatal, grievous, minor and damage accidents. Lorry involved in accidents indicate that scenario II has the lowest percentage and scenario III has the highest percentage of fatal, grievous, minor and damage accidents. Similar trend can be seen accidents involving dual purpose vehicles except damage accidents. Damage accidents of dual purpose vehicle show a decreasing trend when moving towards the scenarios I, II and III. Similar trend can be seen in fatal accidents involving buses.

Table 4. 4: Basic Statistics of Each Scenarios by Types of Vehicles

Type of Vehicle	Type of Accident	Scenario I		Scenario II		Scenario III	
		Mean	%	Mean	%	Mean	%
Motorcycle	Fatal	546	28.3	706	32.7	1,045	63.2
	Grievous	1,383	30.0	2,126	35.0	2,937	54.0
	Minor	3,387	29.5	4,045	33.4	4,435	46.5
	Damage	1,741	12.3	2,017	13.6	1,403	14.4
Lorry	Fatal	368	19.2	365	16.9	350	21.2
	Grievous	630	13.7	749	12.3	824	15.2
	Minor	1,354	11.8	1,259	10.4	1,106	11.6
	Damage	2,301	16.3	1,791	12.1	1,802	18.5
Dual Purpose Vehicle	Fatal	345	18.0	334	15.5	298	18.0
	Grievous	857	18.6	939	15.5	1,045	19.2
	Minor	2,124	18.5	1,894	15.7	1,468	15.4
	Damage	3,477	24.2	3,419	23.4	2,187	22.4
Three-wheel	Fatal	163	8.5	225	10.4	323	19.6
	Grievous	598	13.0	910	15.0	1,275	23.4
	Minor	1,843	16.1	2,308	19.1	2,799	29.4
	Damage	1,781	12.6	2,428	16.4	1,903	19.5
Car	Fatal	135	7.0	160	7.4	178	10.8
	Grievous	419	9.1	567	9.3	839	15.4
	Minor	1,093	9.5	1,254	10.4	1,491	15.6
	Damage	2,461	17.4	3,046	20.5	2,963	30.4
Bus	Fatal	364	19.0	371	17.2	255	15.4
	Grievous	722	15.7	776	12.8	694	12.8
	Minor	1,671	14.6	1,343	11.1	1,059	11.1
	Damage	2,415	17.1	2,072	14.0	1,415	14.5
Other	Fatal	141	7.5	143	6.5	107	6.5
	Grievous	246	5.3	264	4.3	222	4.1
	Minor	706	6.2	536	4.4	343	3.6
	Damage	742	5.3	676	4.6	311	3.2

4.3.1. Fatal and Grievous Accidents by Types of Vehicles

Among the each types of vehicles mentioned in table 4.4, the fitted linear trend line for motorcycle, three-wheel and car involved in fatal accidents were statistically significant and the fitted trend lines were able to explain 86%, 88% and 51% of the observed variability respectively as the corresponding R^2 were .86, .88 and .51. Further, based on the gradient of the fitted linear models, it can be concluded that the fatal road accidents involving motorcycle are increased at a rate of 56, three-wheel are increased at a rate of 17 and car are increased at a rate of 6 per year (Figure 4.7).

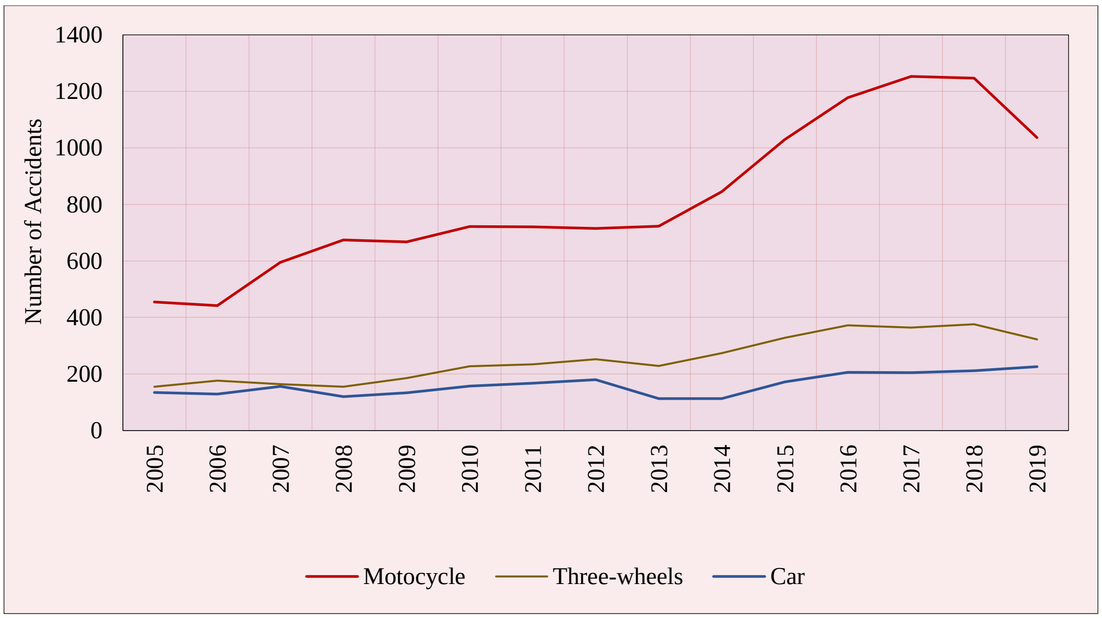

Figure 4. 5:Fatal Accidents Involving Motorcycle, Car and Three-wheel (2005 - 2019)

When advertence to the grievous accidents involving motorcycle, three-wheel and car, figure 4.8 shows that the fitted liner trend line for all three variables were statistically significant and, the fitted trend lines for these three types of vehicles were able to explain 92%, 91% and 89% of the observed variability respectively as the corresponding R^2 were .92, .91 and .89. Further, based on the gradient of the fitted linear models, it can be concluded that grievous accidents involving motorcycle are increased at a rate of 159, three-wheel are increased at a rate of 69 and car are increased at a rate of 47 annually.

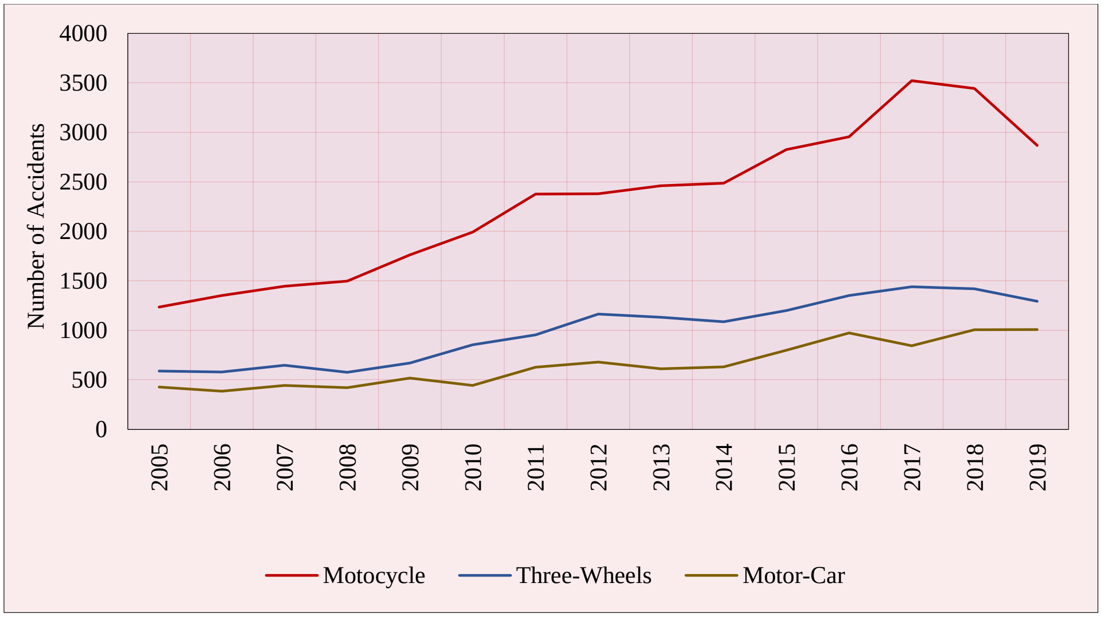

Figure 4. 6: Grievous Accidents Involving Motorcycle, Car and Three-wheel (2005 - 2019)

4.4. RTAs by Days of Week

The dissemination of the RTAs based on the days of the week during the period of 2005 - 2019 is shown in table 4.5. As the chi-square test statistics is significant in table 4.5 (p = .000), it can be concluded with 95% confidence that the days of week have significant association with the type of accident.

Table 4. 5: Days of Week and Type of Accident

Days of Week	**Type of Accident**			
	Fatal	**Grievous**	**Minor**	**Damage**
Monday	5,114 (6%)	14,331 (18%)	27,886 (35%)	32,596 (41%)
Tuesday	5,004 (6%)	13,889 (18%)	26,692 (34%)	32,140 (42%)
Wednesday	5,133 (7%)	14,159 (18%)	27,032 (34%)	32,324 (41%)
Thursday	5,078 (7%)	14,303 (18%)	26,847 (34%)	32,117 (41%)
Friday	5,335 (7%)	14,462 (18%)	27,786 (34%)	33,717 (41%)
Saturday	5,423 (7%)	14,760 (19%)	27,687 (35%)	30,161 (39%)
Sunday	5,453 (7%)	14,820 (20%)	27,736 (38%)	25,936 (35%)

(χ^2_{18}= 1056.467 p = .000)

When moving from weekdays to the weekend grievous road accidents show an increasing trend as the weekend represents the highest percentage of grievous accidents. Same trend can be seen in minor accidents as well. However damage accidents show an opposite trend than the other three types of accidents; as when moving from weekdays to weekend damage accidents show a decreasing trend.

When analyzing to the scattering of the types of road accidents among the days of week based on the three types of scenarios it can be seen that chi-square test statistics is significant where χ^2 = 55.189, df = 12, p = .000, thus it can be concluded with 95% confidence that the numbers of accidents that occur in days of week have significant association with the three types of scenarios. Therefore, table 4.6, 4.7 and 4.8 describe the dispersal of fatal, grievous, minor and damage accidents among the days of the week based on three scenarios by using cross tabulation.

Based on the results of the chi-square test statistics (Table 4.6, 4.7 & 4.8), it can be concluded with 95% confidence that there is a significant association between days of week and type of accident in scenario I, II and III.

Table 4. 6: Days of Week and Type of Accident in Scenario I

Days of Week	**Type of Accident**			
	Fatal	**Grievous**	**Minor**	**Damage**
Monday	1,308 (6%)	2,860 (14%)	7,391 (36%)	9,268 (44%)
Tuesday	1,121 (6%)	2,801 (14%)	6,947 (35%)	9,060 (45%)
Wednesday	1,259 (6%)	2,055 (11%)	7,236 (37%)	8,955 (46%)
Thursday	1,147 (6%)	2,146 (11%)	6,891 (36%)	9,059 (47%)
Friday	1,202 (6%)	2,126 (11%)	7,212 (35%)	9,244 (47%)
Saturday	1,205 (7%)	2,037 (11%)	6,997 (37%)	8,399 (45%)
Sunday	1,297 (7%)	2,836 (15%)	7,047 (38%)	7,466 (40%)

(χ^2_{18} = 560.299 p = .000)

Table 4. 7: Days of Week and Type of Accident in Scenario II

Days of Week	Type of Accident			
	Fatal	Grievous	Minor	Damage
Monday	1,276 (6%)	3,680 (16%)	7,536 (34%)	9,992 (44%)
Tuesday	1,359 (6%)	3,506 (16%)	7,186 (33%)	9,669 (45%)
Wednesday	1,280 (6%)	3,597 (16%)	7,170 (33%)	9,859 (45%)
Thursday	1,333 (6%)	3,642 (17%)	7,340 (33%)	9,774 (44%)
Friday	1,418 (6%)	3,631 (16%)	7,339 (32%)	10,420 (46%)
Saturday	1,409 (6%)	3,755 (17%)	7,510 (34%)	9,345 (42%)
Sunday	1,448 (7%)	3,782 (19%)	7,440 (36%)	7,924 (39%)

(χ^2_{18}= 326.688 p = .000)

Table 4. 8: Days of Week and Type of Accident in Scenario III

Days of Week	Type of Accident			
	Fatal	Grievous	Minor	Damage
Monday	2,530 (7%)	7,791 (21%)	12,959 (35%)	13,336 (37%)
Tuesday	2,524 (7%)	7,582 (21%)	12,559 (35%)	13,411 (37%)
Wednesday	2,594 (7%)	7,784 (21%)	12,626 (35%)	13,510 (37%)
Thursday	2,598 (7%)	7,806 (21%)	12,616 (35%)	13,284 (37%)
Friday	2,715 (7%)	7,989 (21%)	13,235 (35%)	14,053 (37%)
Saturday	2,414 (7%)	8,300 (23%)	13,180 (36%)	12,417 (34%)
Sunday	2,708 (8%)	8,202 (24%)	13,249 (38%)	10,546 (30%)

(χ^2_{18}= 608.345 p = .000)

According to the table scenario I, weekend has high propensity to occur fatal, grievous and minor accidents. Damages accidents are less during the weekend than during weekdays. Similar trend was found in scenario II and scenario III (Table 4.7 & 4.8).

4.5. RTAs by Time of the Day

There are some times of the day where road users are more vulnerable to experiencing a collision. Results in table 4.9 indicate that time of the day is also significantly associated with the type of accidents as the corresponding chi-square statistic is significant.

Table 4. 9: Time of the Day and Types of Accident

Time of the Day	Types of Accident			
	Fatal	**Grievous**	**Minor**	**Damage**
Midnight - 4 a.m.	2778 (10%)	4815 (17%)	8436 (29%)	12845 (44%)
4 - 8 a.m.	4024 (7%)	10691 (19%)	19219 (35%)	21332 (39%)
8 - 12 noon	5935 (5%)	19039 (17%)	38457 (34%)	48643 (44%)
12 noon - 4 p.m.	6796 (5%)	22114 (18%)	43683 (35%)	53148 (42%)
4 - 8 p.m.	10349 (7%)	28940 (19%)	54848 (37%)	54551 (37%)
8 - Midnight	6658 (8%)	15125 (20%)	27023 (35%)	28472 (37%)

(χ^2_{15} = 3579.616 p = .000)

Table 4. 10: Time of the Day and Types of Accident in Scenario I

Time of the Day	Types of Accident			
	Fatal	**Grievous**	**Minor**	**Damage**
Midnight - 4 a.m.	788 (9%)	1185 (13%)	2780 (31%)	4194 (47%)
4 - 8 a.m.	866 (6%)	2169 (14%)	5370 (36%)	6541 (44%)
8 - 12 noon	1601 (5%)	4102 (13%)	10812 (35%)	14330 (47%)
12 noon - 4 p.m.	1654 (5%)	4489 (14%)	11474 (35%)	14813 (46%)
4 - 8 p.m.	2335 (7%)	5309 (15%)	13275 (37%)	14628 (41%)
8 - Midnight	1471 (7%)	2868 (15%)	6979 (36%)	8177 (42%)

(χ^2_{15}= 576.584 p = .000)

Table 4. 11: Time of the Day and Types of Accident in Scenario II

Time of the Day	Types of Accident			
	Fatal	Grievous	Minor	Damage
Midnight - 4 a.m.	764 (10%)	1193 (15%)	2244 (29%)	3646 (46%)
4 - 8 a.m.	836 (7%)	2184 (18%)	4121 (34%)	5049 (41%)
8 - 12 noon	1548 (5%)	4929 (15%)	10331 (32%)	15295 (48%)
12 noon - 4 p.m.	1776 (5%)	5546 (15%)	11676 (33%)	16594 (47%)
4 - 8 p.m.	2662 (6%)	7398 (18%)	14803 (36%)	16608 (40%)
8 - Midnight	1761 (8%)	3898 (18%)	7377 (34%)	8559 (40%)

(χ^2_{15} = 1186.085 p = .000)

Table 4. 12: Time of the Day and Types of Accident in Scenario III

Time of the Day	Types of Accident			
	Fatal	Grievous	Minor	Damage
Midnight - 4 a.m.	1226 (10%)	2437 (20%)	3412 (28%)	5005 (42%)
4 - 8 a.m.	2322 (8%)	6338 (22%)	9728 (35%)	9742 (35%)
8 - 12 noon	2786 (6%)	10008 (20%)	17314 (35%)	19018 (39%)
12 noon - 4 p.m.	3366 (6%)	12079 (21%)	20533 (35%)	21741 (38%)
4 - 8 p.m.	5352 (8%)	16233 (23%)	26770 (37%)	23315 (32%)
8 - Midnight	3426 (10%)	8359 (23%)	12667 (35%)	11736 (32%)

(χ^2_{15} = 1774.960 p = .000)

According to the table 4.9, fatal and damage accidents mostly occurred during the period from midnight - 4 a.m. Grievous and minor accidents mostly occurred during the period from 4 - 8 p.m. Further, it can be see that in all time intervals ranking order of accidents are damage > minor > grievous > fatal. Similar trend can be seen in scenario I and III. But the scenario II indicated that most of the damage accidents occurred during 8 a.m. - 12 noon (Table 4.10, 4.11 & 4.12).

4.6. Summary of Chapter Four

During the period of 2005 - 2019, fatal and grievous accidents indicated an increasing trend and minor and damage accidents indicated a decreasing trend. Pedestrians and motorcyclists were more vulnerable road users as represented an increasing trend with 29% and 27% of all deaths due to RTAs respectively. Accidents involving motorcycles also represented an increasing trend when moving from each scenarios. The weekend has high propensity to occurrences of fatal, grievous, minor accidents and weekdays have high propensity to occurrences damage accidents. Time of the day from midnight to 4 a.m. indicated higher number of fatal and damage accidents. Grievous and minor accidents are highly reported at 4 - 8 p.m. Among the three scenarios, fatal, grievous, minor accidents are high in scenario III and damage accidents are high in scenario II. Sunday is a high risk day in scenario II and III; on Sundays most fatal, grievous and minor accidents occur.

CHAPTER 05

IDENTIFYING KEY FACTORS OF ROAD TRAFFIC ACCIDENTS (RTAs)

Accidents occur due to a variety of reasons. The Sri Lanka Police have identified 25 causes of RTAs (Section 1.4) under seven categories as the causes associated with RTAs in Sri Lanka. This chapter focuses on identifying key factors of RTAs from those causes during the period of 2005 - 2019 using explanatory factor analysis and confirmatory factor analysis.

5.1. Descriptive Statistics of the Initial Variables

The table 5.1 describes the mean value of the each observed variables and the variance of them to recognize the scattering of RTAs data over 15 (2005 - 2019) years for each of the observed variables.

Table 5. 1: Basic statistics of the RTAs (per year) among the seven categories during 2005 - 2019

Reasons	Mean	Variance	% of Variance with respective to Total
Overtaking	5,861	3,459,088	43.4
Speed driving	4,606	3,517,139	44.2
Diversion	5,024	624,558	7.8
Alcohol consumption of driver	1,610	106,825	1.3
Mechanical faults of vehicle	453	64,556	0.8
Negligence of pedestrians	1,006	191,999	2.4
Others	16,971	19,854,402	-

Table 5.1 shows that there is a high variance in accidents due to overtaking, accidents due to speed driving and accidents during diversion compared with the variance in other

variables except others. Mean values of the seven categories also indicate a similar trend. More than 90% of the variability of the initial system is acquired by accidents during overtaking, accidents due to speed driving, accidents during diversion; if other reasons are disregarded as shown in table 5.1. Thus, it can be concluded that the highest rate of accidents occur due to the overtaking, speed driving and during the diversion. Alcohol consumption, mechanical faults and negligence of pedestrians represent a low rate during the period of 2005 - 2019. Because of uneven distribution of the contribution of variance from each variable, standardization is required prior to Explanatory Factor Analysis (EFA).

5.2. Diagnostic Tests for Explanatory Factor Analysis (EFA)

The significance of Bartlett's test of Sphericity (Table 5.2) ratified that the observed correlation matrix is significantly different form the identity matrix. Results in table 5.2, also indicated that the KMO statistic (0.747) is greater than 0.6 confirming that data satisfied sample adequacy for FA.

Table 5. 2: Results of KMO and Bartlett's test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.747
Bartlett's Test of Sphericity	Approx. Chi-Square	121.555
	df	21
	Sig.	0.00

Reliability statistic is not done in this case as all variables are continuous. The results of normality test for each variable is shown in Table 5.3.

According to the results of the table 5.3, it can be concluded that all the variables are not significantly deviated from normal distribution at 5% level. Thus for FA, factors can be extracted using Maximum Likelihood Factoring (MLF) in addition to Principal Axis Factoring (PAF) and Principle Component Analysis (PCF).

Table 5. 3: Results of the AD test for Normality

Variable	AD Statistics	P-value
Overtaking	0.678	0.061
Speed driving	0.447	0.242
Diversion	0.356	0.408
Alcohol consumption of driver	0.227	0.775
Mechanical faults of vehicle	0.403	0.313
Negligence of pedestrians	0.356	0.410
Other	0.201	0.854

5.3. Eigen Analysis for Correlation Matrix Analysis

Eigen analysis for the correlation matrix in table 5.4, indicated that only two eigenvalues are greater than one.

Table 5. 4: Total Variance Explained (Correlation Matrix Analysis)

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.030	71.862	71.862	5.030	71.862	71.862
2	1.344	19.204	91.066	1.344	19.204	91.066
3	.360	5.140	96.205			
4	.150	2.144	98.350			
5	.065	.922	99.272			
6	.035	.493	99.765			
7	.016	.235	100.000			

Thus, only first two components can be used as common factors which accounted 91% of the variance across seven observed variables. Thus, 7D initial system can be reduced to 2D system. Factors were initially extracted using PCF method.

5.4. Results of 2 - Factor Model after Rotation

5.4.1. Under PCF Method

The following tables show the factor rotation results under the three types of rotation methods in PCF method.

Table 5. 5: Factor Loadings of 2 - Factor Model (PCF and Varimax)

Reasons	Component	
	1	2
Overtaking	.482	**.773**
Speed driving	.675	**.699**
Diversion	.400	**.892**
Alcohol consumption of driver	-.018	**.915**
Mechanical faults of vehicle	**.898**	.301
Negligence of pedestrians	**.935**	.313
Other	**-.965**	-.073

Table 5. 6: Factor Loadings of 2 - Factor Model (PCF and Quartimax)

Reasons	Component	
	1	2
Overtaking	.600	**.686**
Speed driving	.555	**.798**
Diversion	.538	**.817**
Alcohol consumption of driver	.128	**.906**
Mechanical faults of vehicle	**.935**	.153
Negligence of pedestrians	**.973**	.159
Other	**-.965**	.083

Table 5. 7: Factor Loadings of 2 - Factor Model (PCF and Equamax)

Reasons	Component	
	1	2
Overtaking	.482	**.773**
Speed driving	.675	**.699**
Diversion	.400	**.892**
Alcohol consumption of driver	-.018	**.915**
Mechanical faults of vehicle	**.898**	.301
Negligence of pedestrians	**.935**	.313
Other	**-.965**	-.073

Based on the results in table 5.5. - 5.7, it can be easily confirmed that among the initial seven variables, mechanical faults of vehicle, negligence of pedestrians and other reasons load more highly on the first common factor, irrespective of three rotation methods. Similarly, the initial variables; speed driving, accidents due to overtaking, accidents during diversion and accidents due to alcohol consumption of driver load more highly on the second common factor, irrespective of types of rotation.

Thus, based on the results of PCF method; the two common factors can be derived using {mechanical faults of vehicle, negligence of pedestrians, other reasons} and {speed driving, overtaking, diversion, alcohol consumption of driver} irrespective of the types of rotation.

The following tables (Table 5.8 - 5.10) show the factor rotation results under the three types of rotation in PCF method using covariance matrix analysis.

The summary of the covariance analysis also same as the results of the correlation matrix analysis. Thus it can be conclude that two factors are same invariant on the type of analysis methods (correlation matrix and covariance matrix).

Table 5. 8: Factor Loadings of 2 - Factor Model Covariance Analysis (PCF and Varimax)

Reasons	Raw Component		Rescaled Component	
	1	2	1	2
Overtaking	742.078	**1,673.556**	.399	**.900**
Speed driving	1,290.431	**1,318.695**	.688	**.703**
Diversion	288.609	**689.233**	.365	**.872**
Alcohol consumption of driver	12.637	**226.149**	.039	**.692**
Mechanical faults of vehicle	**210.510**	79.484	**.829**	.313
Negligence of pedestrians	**386.056**	157.295	**.881**	.359
Other	**-4,438.711**	-386.918	**-.996**	-.087

Table 5. 9: Factor Loadings of 2 - Factor Model Covariance Analysis (PCF and Quartimax)

Reasons	Raw Component		Rescaled Component	
	1	2	1	2
Overtaking	773.873	**1,659.093**	.416	**.892**
Speed driving	1,293.835	**1,315.355**	.690	**.701**
Diversion	301.706	**683.602**	.382	**.865**
Alcohol consumption of driver	16.949	**225.867**	.052	**.691**
Mechanical faults of vehicle	**211.988**	75.453	**.834**	.297
Negligence of pedestrians	**388.986**	149.901	**.888**	.342
Other	**-4,445.285**	-302.162	**-.998**	-.068

Table 5. 10: Factor Loadings of 2 - Factor Model Covariance Analysis (PCF and Equamax)

Reasons	Raw Component		Rescaled Component	
	1	2	1	2
Overtaking	1,152.940	**1,422.041**	.620	**.765**
Speed driving	936.426	**1,589.741**	.499	**.848**
Diversion	458.406	**590.086**	.580	**.747**
Alcohol consumption of driver	71.191	**215.023**	.218	**.658**
Mechanical faults of vehicle	**223.955**	21.819	**.881**	.086
Negligence of pedestrians	**413.721**	51.145	**.944**	.117
Other	**-4,385.964**	784.332	**-.984**	.176

5.4.2. Under PAF Method

The following tables show the factor rotation results under the three types of rotation methods in PAF method.

Based on the results in table 5.11. - 5.13, similar results can be identified as in PCF method. Thus it can be concluded that the two common factors can be formed using {mechanical faults of vehicle, negligence of pedestrians, other reasons} and {speed driving, overtaking, diversion, alcohol consumption of driver} irrespective of the types of factor extraction method.

Table 5. 11: Factor Loadings of 2 - Factor Model (PAF and Varimax)

Reasons	**Component**	
	1	2
Overtaking	.448	**.787**
Speed driving	.673	**.704**
Diversion	.368	**.911**
Alcohol consumption of driver	.019	**.808**
Mechanical faults of vehicle	**.877**	.322
Negligence of pedestrians	**.926**	.334
Other	**-.961**	-.091

Table 5. 12: Factor Loadings of 2 - Factor Model (PAF and Quartimax)

Reasons	**Component**	
	1	2
Overtaking	.510	**.748**
Speed driving	.647	**.727**
Diversion	.440	**.879**
Alcohol consumption of driver	.084	**.804**
Mechanical faults of vehicle	**.900**	.250
Negligence of pedestrians	**.950**	.258
Other	**-.965**	-.014

Table 5. 13: Factor Loadings of 2 - Factor Model (PAF and Equamax)

Reasons	Component	
	1	2
Overtaking	.448	**.787**
Speed driving	.673	**.704**
Diversion	.368	**.911**
Alcohol consumption of driver	.019	**.808**
Mechanical faults of vehicle	**.877**	.322
Negligence of pedestrians	**.926**	.334
Other	**-.961**	-.091

5.4.3. Under MLF Method

As all the variables are normally distributed the MLF method can also be applied to decide the two common factors. When MLF extraction method is used it is better to decide the number of factors first using the hypothesis test. The results of the goodness of fit test of the hypothesis,

H_0: q factors are sufficient

H_1: more factors are needed

Table 5. 14: Results of the Significance Test

Null Hypothesis	Chi-Square Test Statistics	P-Value	Decision
H_0: q =1	49.361	.000	*Ho* is rejected
H_0: q =2	11.825	.159	*Ho* is not rejected

Based on the results for the hypothesis in table 5.14, it can be concluded that one factor is not sufficient to be common factors to represent the original seven variables as the p-value is less than 5%. Results indicate that the hypothesis 2 is not rejected. Thus 2 - factors can be accepted to represent the original system of seven variables. Therefore, it is recommended that the correlation structure in seven observed variables can be explained using the two common factors.

It should be noted that the minimum number of factors obtained by the MLF is also two as eigenvalue is greater than one criterion (Table 5.15). As shown in the table 5.15, the two common factors accounted for 88% of the variance across seven observed variables.

Table 5. 15: Total Variance Explained in MLF

Component	**Initial Eigenvalues**			**Extraction Sums of Squared Loadings**		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.030	71.862	71.862	4.381	62.589	62.589
2	1.344	19.204	91.066	1.770	25.284	87.873
3	.360	5.140	96.205			
4	.150	2.144	98.350			
5	.065	.922	99.272			
6	.035	.493	99.765			
7	.016	.235	100.000			
8	5.030	71.862	71.862			

Table 5. 16: Factor Loadings of the 2 - Factor Model (MLF and Varimax)

Reasons	**Component**	
	1	2
Overtaking	.453	**.779**
Speed driving	.649	**.700**
Diversion	.365	**.931**
Alcohol consumption of driver	.021	**.810**
Mechanical faults of vehicle	**.896**	.311
Negligence of pedestrians	**.940**	.330
Other	**-.931**	-.106

Table 5. 17: Factor Loadings of the 2 - Factor Model (MLF and Quartimax)

Reasons	Component	
	1	2
Overtaking	.508	**.744**
Speed driving	.651	**.698**
Diversion	.431	**.902**
Alcohol consumption of driver	.080	**.807**
Mechanical faults of vehicle	**.917**	.245
Negligence of pedestrians	**.962**	.261
Other	**-.937**	-.038

Table 5. 18: Factor Loadings of the 2 - Factor Model (MLF and Equamax)

Reasons	Component	
	1	2
Overtaking	.453	**.779**
Speed driving	.649	**.700**
Diversion	.365	**.931**
Alcohol consumption of driver	.021	**.810**
Mechanical faults of vehicle	**.896**	.311
Negligence of pedestrians	**.940**	.330
Other	**-.931**	-.106

Table 5.16, 5.17 and 5.18 show the results of the factor loading of the MLF and three factor rotation methods.

According to the results of the two factor model with three rotation under the MLF method, it can be conclude that the division of the initial variables between the two factors are same irrespective of the types of rotation method.

Thus on the view of the above analysis the summary of the two factor model shown in table 5.19.

5.4.4. Summary of the 2 - Factor Model

It can be concluded that the two common factors are invariant on the types of analysis methods (correlation matrix and covariance matrix), types of extraction methods (PCF, PAF and MLF) and also the types of rotation methods (Varimax, Quartimax and Equamax). Therefore, based on the results it can be concluded that the two common factors can be formed using {mechanical faults of vehicle, negligence of pedestrians, other reasons} and {speed driving, overtaking, diversion, alcohol consumption of driver} irrespective of the type of analysis, extraction method and rotation method.

Table 5. 19: Summary of the 2 - Factor Model

Type of rotation	Factor 1	Factor 2
Varimax	Mechanical faults of vehicle	Overtaking
	Negligence of pedestrians	Speed driving
	Other	Diversion
		Alcohol consumption of driver
Quartimax	Mechanical faults of vehicle	Overtaking
	Negligence of pedestrians	Speed driving
	Other	Diversion
		Alcohol consumption of driver
Equamax	Mechanical faults of vehicle	Overtaking
	Negligence of pedestrians	Speed driving
	Other	Diversion
		Alcohol consumption of driver

5.2.6. Factor Score Coefficient

Out of the two types of extraction methods and three types of rotation methods; PCF with Varimax rotation method is more popular and efficient. Therefore, factor score coefficient was obtained for the combination of PCF Varimax rotation method (Table 5.20).

Table 5. 20: Factor Score Coefficient of Selected Factors from Varimax (PCF)

Reasons	Component	
	1	2
Overtaking	-.088	.676
Speed driving	.005	.466
Diversion	-.016	.119
Alcohol consumption of driver	-.004	.018
Mechanical faults of vehicle	.002	.002
Negligence of pedestrians	.006	.008
Other	-1.035	.646

The key factors (F1 and F2) of RTAs can be defined as,

$$F1 = 0.678\ Z_1 + 0.466\ Z_2 + 0119\ Z_3 + 0.018\ Z_4$$

$$F2 = 0.002\ Z_5 + 0.06\ Z_6 – 1.035\ Z_7$$

Where $Z_i = \frac{[X_i - \bar{X}_i]}{SD_{X_i}}$

Z_i - Standard Score

X_i - Observed Value

$\bar{X}_i$ - Mean of the Sample

SD_{X_i} - Standard deviation of the sample

Thus F1 and F2 can be written as;

F1 = .002* [(Mechanical fault of vehicle - 452.67) / 254.07] + .006* [(Negligence of pedestrians - 1006.00) / 438.17] – 1.035* [(Other – 16971.07) / 4455.82]

F2 = .676* [(Overtaking - 5860.73) / 1859.86] + 0.466 * [(Speed driving - 4606.47) / 1875.40] + .119* [(Diversion – 5024.27) / 790.29] + .018* [(Alcohol consumption of driver – 1609.53) / 326.84]

The two factors can be named as, "negligence of pedestrians and other external reasons" and "lack of attention of the driver".

5.3. Confirmatory Factor Analysis (CFA)

In order to further justify the structure of the two factors identified using EFA, CFA was also carried out. In other words, CFA further evidence regarding the key factors of the suggested model with regard to the factors identified by EFA.

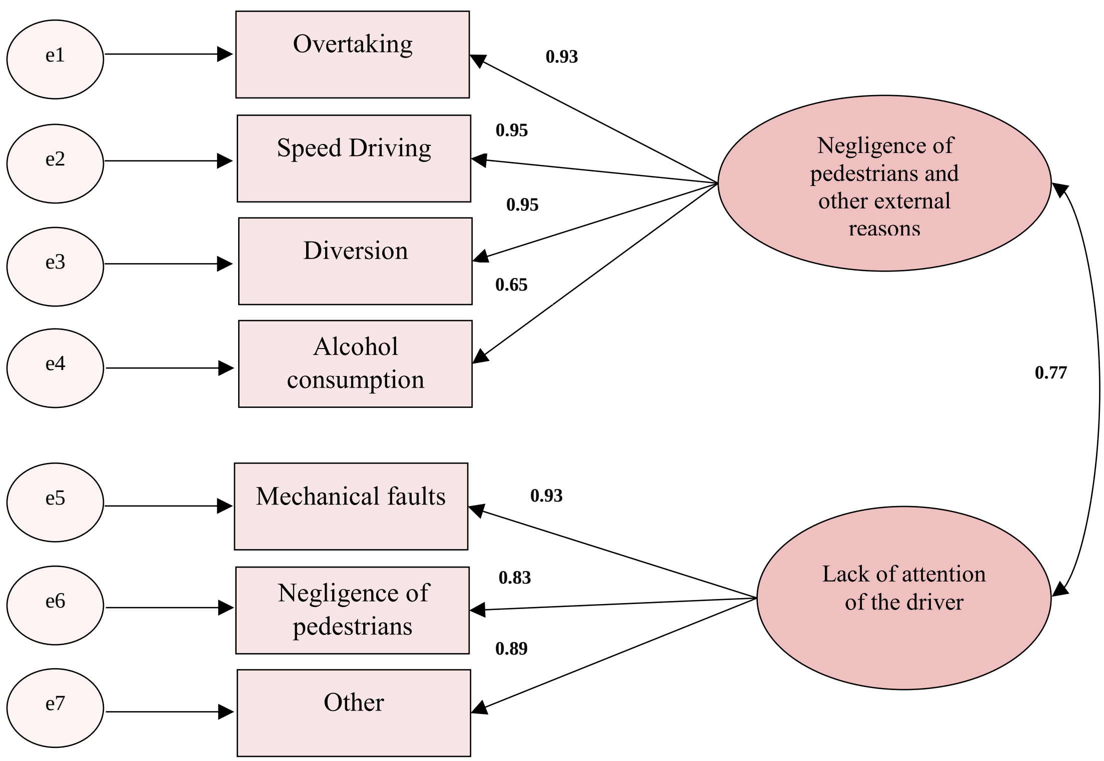

Figure 5. 1: Standardized Parameter Estimates for 2 - Factor CFA Initial Model

According to the figure 5.1, all the variables of the two factors indicated high loading values (> 0.8) with an exception for alcohol consumption. This justified the validity of the variables selected for the two factors using EFA. However, comparatively low loadings for alcohol is reflected from the results in table 5.21. The results in table 5.21 indicates that H_0

is rejected confirming the model is not significant at 95% confidence level where $\chi^2_{13} = 33.822$.

Table 5. 21: Model Chi-Square Statistics

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	15	33.822	13	0.001	2.602
Saturated model	28	0	0		
Independence model	7	157.086	21	0	7.48

Moreover, the CMIN value is close to 3, indicating that the model is moderately fit. Therefore, it is necessary to check whether there can be any improvements to the initial model.

The results of table 5.22, indicate that there are no possible improvements to the model as all the standardized residuals covariance values are less than 4 (Singh & Nayak, 2015). But the results of the modification indices (Table 5.23) suggested the improvements to the model.

Table 5. 22: Standardized Residual Covariances

	Mechanical faults	Negligence of pedestrians	Other	Overtaking	Speed Driving	Diversion	Alcohol consumption
Mechanical faults	.000						
Negligence of pedestrians	.011	.000					
Other	-.074	.000	.000				
Overtaking	-.155	-.123	.500	.000			
Speed Driving	.315	.286	-.293	-.012	.000		
Diversion	-.175	-.270	.659	.033	-.029	.000	
Alcohol consumption	-.485	-.751	1.201	-.148	-.175	.460	.000

Table 5. 23: Modification Indices

			M.I.	Par Change
e2	<-->	e7	6.869	-839,832.525
e4	<-->	e3	7.109	51,177.646

Singh and Nayak (2015), claimed that it is possible make improvements in the model by looking at the modification indices. They have suggested that to check whether there is any relationship between error terms within the same constant. And also mentioned that there is no conceivable to draw relationship between constant and error. Table 5.23, indicated that there is a possibility to draw the relationship between e4 and e3 which are the same constant term.

The finalized model is shown in figure 5.2 and the standardized residual covariances and modification indices of that model indicated that the model cannot be further improved.

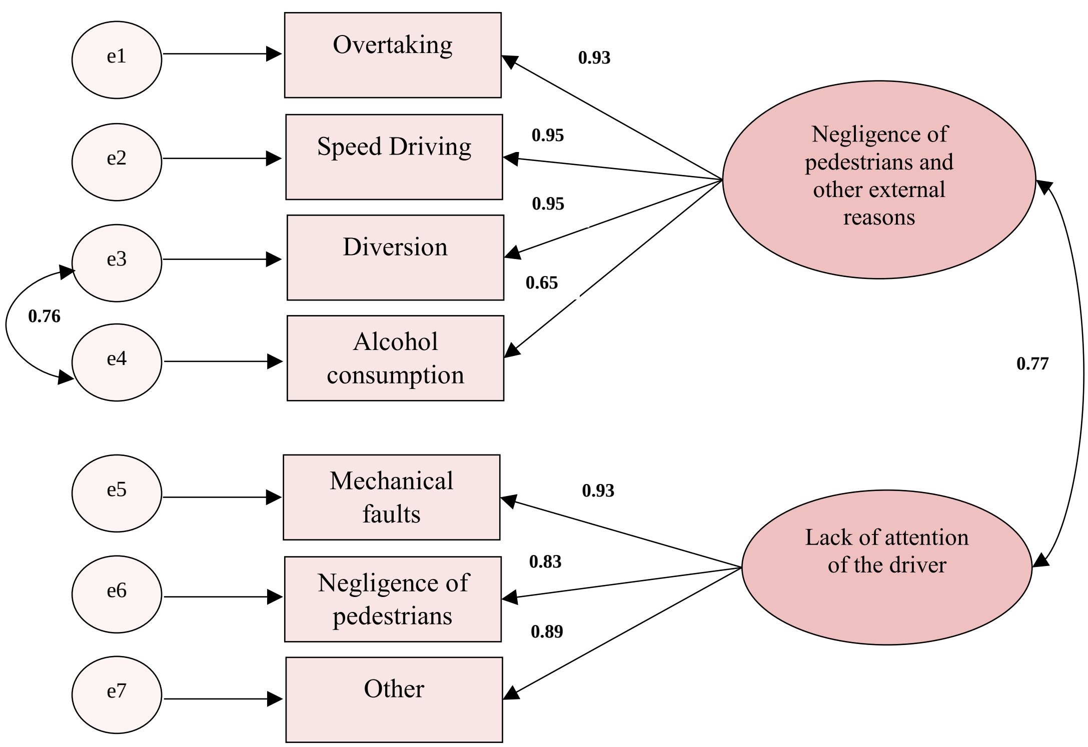

Figure 5. 2: Standardized Parameter Estimates for 2 - Factor CFA Finalized Model

Table 5. 24: Model Chi-Square Statistics (Finalized Model)

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	16	25.046	12	.015	2.087
Saturated model	28	.000	0		
Independence model	7	157.086	21	.000	7.480

According to the table 5.24, finalized model chi square statistic designates the model is significant at 99% confidence level where $\chi^2_{12} = 25.046$.

Table 5. 25: Model Fit Summary of Finalized Model

RMSEA	.089
NFI	.841
NNFI (TLI)	.832
CFI	.904
GFI	.930
AGFI	.870
PGFI	.517
PNFI	.480

All the model fit summary statistics in table 5.25, indicate that moderately fitted model on the basis of the criteria mentioned in section 3.5. Thus it can be concluded that the finalized structural model was considered to be appropriate for further analysis, and it proved to be the best model for the study.

5.3. Summary of the Chapter Five

Of the seven observed variables, two common factors were identified irrespective of factor extraction methods in (i) PCF (ii) PAF and (iii) MLF and three types of orthogonal rotations. CFA further evidence regarding the two factors suggested model with regard to the factors identified via EFA. The two factors identified are (i) negligence of pedestrians and other external reasons (ii) lack of attention of the driver.

CHAPTER 06

IDENTIFICATION OF RISK FACTORS ON ROAD TRAFFIC ACCIDENTS (RTAs)

The purpose of this chapter is to determine the significantly associated risk factors with RTAs in Sri Lanka during the period of 2005 - 2019 using binary logistic regression due to the dichotomous nature of the severity of accident as outcome variable. The road characteristics, time & environmental characteristics, vehicle characteristics and human & accidents characteristics are considered as the explanatory variables.

6.1. Description of Variables Used

According to the Sri Lanka Police Database, RTAs are classified as fatal, grievous, minor and damage accidents. But, the current trend of RTAs claim that the damage and minor accidents are under reported (Section 2.3). Thus, to identify the risk factors associated with RTAs, those four categories of RTAs are classified into two categories as fatal and non-fatal accidents. All the grievous, minor and damage accidents are considered as non-fatal accidents. Thus the dependent variable, severity of accident is a binary variable such that severity of accident = 1 for fatal and equals to 0 for non-fatal.

Table 6. 1: Independent Variables

Road Characteristics	Road surface	1- “Dry” 2- “Wet”
	Light condition	1- “Daylight” 2- “Night, improper street lighting 3- “Night, good street lighting”
	Location type	1- “Road no junction with 10 meters”, 2- “Junction”, 3- “Other”
Time & Environmental Characteristics	Sector	1- “Urban” 2- “Rural”
	Type of day	1-“Normal working day” 2- “Normal weekend” 3- “Holiday”

Time & Environmental Characteristics	Day of week	1- “Weekday” 2- “ Weekend”
	Weather	1- “Clear” 2- ”Humid”
Vehicle Characteristics	Vehicle type	1- “Two wheels” 2- “Three wheels” 3- “More than three wheels”
	Vehicle ownership	1- “Private vehicle” 2- “Government vehicle” 3- “Service vehicle”
	Age of vehicle	1- “Less than 10 years” 2- “10 - 30 years” 3- “More than 30 years”
Human & Accident Characteristics	Alcohol test	1- “No alcohol or below legal limit” 2- “Over legal limit” 3- “Not tested”
	Validity of license	1- “Valid license” 2- “ No license”
	Age of the driver	1- “Less than 18 years” 2- “18 - 40 years” 3- “40 - 60 years” 4- “More than 60 years”
	Gender of the driver	1- “ Male” 2- “Female”
	Key causes of RTAs	1- “Accidents due to negligence of pedestrians and other external reasons” 2- “Accidents due to the lack of attention of the driver”

6.2. Association between Road Characteristics and Severity of Accident

6.2.1. Types of Road Surface

As the chi-square test statistic is significant in table 6.2 (p=.000), it can be concluded with 95% confidence the status of road surface has a significant association with the severity of accident. Thus it can be confirmed with 95% confidence that the percentage of fatal accidents when road surface is wet (7.7%) is significantly higher than that when the road is dry (5.6%).

Table 6. 2: Road Surface and Severity of Accident

Variable	Categories	Severity of Accident			
		Fatal		Non-Fatal	
		Frequency	Percentage	Frequency	Percentage
Road surface	Dry	29003	5.6%	486047	94.4%
	Wet	2551	7.7%	30477	92.3%

(χ_1^2 = 250.507 p = .000)

6.2.2. Types of Light Condition

As table 6.3, the chi-square statistic is significant, it can be concluded with 95% confidence that there is a significant association between light condition and severity of accident.

Table 6. 3: Light Condition and Severity of Accident

Variable	Categories	Severity of Accident			
		Fatal		Non-Fatal	
		Frequency	Percentage	Frequency	Percentage
Light condition	Daylight	17105	4.7%	346367	95.3%
	Night, improper street lighting	12123	8.4%	132434	91.6%
	Night, good street lighting	2326	5.8%	37723	94.2%

(χ_2^2 = 2582.049 p = .000)

Comparing two binomial distributions separately, it was found that the percentage of fatal accident during the night with good street lighting (5.8%) is significantly higher than during daylight (4.7%) and the percentage of fatal accidents when driving in dark with improper street lighting (8.4%) is significantly higher than driving during night with good street lighting.

6.2.3. Types of Location

Results in the table 6.4 indicate that the chi-square statistic is significant (p = .000), and it can be concluded that with 95% confidence there is significant association between location type and severity of accident; the percentage of fatal accidents on the road when there is no junction within 10 meters (6.2%) is significantly higher than that when there is a junction (4.3%).

Table 6. 4: Location Type and Severity of Accident

Variable	Categories	Severity of Accident			
		Fatal		Non-Fatal	
		Frequency	Percentage	Frequency	Percentage
Location type	Road no junction within 10 meters	23110	6.2%	349737	93.8%
	Junction	5679	4.3%	125542	95.7%
	Other	2765	6.3%	41245	93.7%

(χ^2_2 = 650.20 p = .000)

6.3. Association between Time, Environmental Characteristics and Severity of Accident

6.3.1. Types of Sector

The results of the chi-square analysis shown in table 6.5, conclude with 95% confidence that there is significant association between sector and severity of accident.

Table 6. 5: Sector and Severity of Accident

Variable	Categories	Severity of Accident			
		Fatal		Non-Fatal	
		Frequency	Percentage	Frequency	Percentage
Sector	Urban	11069	3.9%	274082	96.1%
	Rural	20485	7.8%	242442	92.2%

(χ_1^2 = 3853.123 p = .000)

Thus it can be stated that the percentage of fatal accidents occurrences in rural area (7.8%) is significantly higher than in urban area (3.9%). In fact, the rate of fatal accidents in rural area is almost double than urban.

6.3.2. Type of Day

The significance of chi-square test statistic in table 6.6 concluded that types of day is significantly associated with the severity of accident with 95% confidence. Comparing two binomial distributions separately, it was found that the percentage of fatal accidents during normal weekend (6.3%) is significantly higher than during normal working day (5.5%). Similarly, it was found that the percentage of fatal accidents during holiday (7.7%) is significantly higher than in normal weekend.

Table 6. 6: Type of Day and Severity of Accident

Variable	Categories	Severity of Accident			
		Fatal		Non-Fatal	
		Frequency	Percentage	Frequency	Percentage
Type of day	Normal working day	21504	5.5%	370499	94.5%
	Normal weekend	9106	6.3%	134759	93.7%
	Holiday	944	7.7%	11266	92.3%

(χ_2^2 = 227.830 p = .000)

6.3.3. Day of Week

The significance of chi-square statistic in table 6.7 confirmed that day of week is significantly associated with severity of accident at 95% confidence. This leads to confirm that the percentage of fatal accidents during weekends (6.3%) is significantly higher than that during weekdays (5.6%).

Table 6. 7: Day of Week and Severity of Accident

Variable	Categories	Severity of Accident			
		Fatal		Non-Fatal	
		Frequency	Percentage	Frequency	Percentage
Day of week	Weekday	22095	5.6%	375772	94.4%
	Weekend	9459	6.3%	140752	93.7%

(χ_1^2 = 111.179 p = .000)

6.3.4. Type of Weather

Results in the table 6.8 indicate that the chi-square statistic is significant (p = .000), thus it can be concluded that with 95% confidence there is significant association between weather and the severity of accident; confirming the rate of fatal accidents when humid weather (7.7%) is significantly higher than that in clear weather (5.6%).

Table 6. 8: Weather and Severity of Accident

Variable	Categories	Severity of Accident			
		Fatal		Non-Fatal	
		Frequency	Percentage	Frequency	Percentage
Weather	Clear	28367	5.6%	478532	94.4%
	Humid	3187	7.7%	37992	92.3%

(χ_1^2 = 322.418 p = .000)

6.4. Association between Vehicle Characteristics and Severity of Accident

6.4.1. Type of Vehicle

As table 6.9, the significance of chi-square test statistic concludes that type of vehicle is significantly associated with the severity of accident with 95% confidence. This leads to confirm that the percentage of fatal accidents by two wheels vehicles (6.1%) are significantly higher than three wheels (5.6%) and four wheels vehicles (5.6%).

Table 6. 9: Type of Vehicle and Severity of Accident

Variable	Categories	Severity of Accident			
		Fatal		Non-Fatal	
		Frequency	Percentage	Frequency	Percentage
Vehicle type	Two wheels	9699	6.1%	148052	93.9%
	Three wheels	3357	5.6%	56302	94.4%
	More than three wheels	18498	5.6%	312170	94.4%

(χ_2^2 = 62.542 p = .000)

6.4.2. Type of Vehicle Ownership

The chi-square test statistic in table 6.10 reveals that there is significant association between vehicle ownership and severity of accident with 95% confidence level. Comparing two binomial distributions separately, it was found that the percentage of fatal accidents by government vehicle (5.9%) is significantly higher than by private vehicle (5.7%). Similarly, it was found that the percentage of fatal accidents by service vehicle (6.8%) is significantly higher than by government vehicle.

Table 6. 10: Vehicle Ownership and Severity of Accident

Variable	Categories	Severity of Accident			
		Fatal		Non-Fatal	
		Frequency	Percentage	Frequency	Percentage
Vehicle ownership	Private vehicle	30196	5.7%	495232	94.3%
	Government vehicle	1133	5.9%	18187	94.1%
	Service vehicle	225	6.8%	3105	93.2%

(χ_2^2 = 6.643 p = .036)

6.4.3. Type of Vehicle Age

As the chi-square test statistic is significant (p=.000) in table 6.11, it can be concluded with 95% confidence that the vehicle age is significantly associated with the severity of accident.

Table 6. 11: Vehicle Age and Severity of Accident

Variable	Categories	Severity of Accident			
		Fatal		Non-Fatal	
		Frequency	Percentage	Frequency	Percentage
Vehicle age	Less than 10 years	24425	5.9%	392532	94.1%
	10 - 30 years	6928	5.4%	120378	94.6%
	More than 30 years	201	5.3%	3614	94.7%

(χ_2^2 = 32.784 p = .000)

Comparing two binomial distributions separately, it can be concluded that the percentage of occurring fatal accidents when the vehicle age 10 - 30 years (5.4%) is not significantly different from the percentage of fatal accidents when the age of the vehicle is more than 30 years. However, the percentage of occurring fatal accidents by vehicle age less than 10 years (5.9%) is significantly higher than that of other two types of vehicles.

6.5. Association between Human, Accident Characteristics and Severity of Accident

6.5.1. Type of Alcohol Test

The significance of chi-square statistic in table 6.12, confirms that alcohol test is significantly associated with severity of accident.

Table 6. 12: Alcohol Test and Severity of Accident

Variable	Categories	Severity of Accident			
		Fatal		Non-Fatal	
		Frequency	Percentage	Frequency	Percentage
Alcohol test	No alcohol or below legal limit	6344	4.1%	149301	95.9%
	Over legal limit	529	3.2%	16045	96.8%
	Not tested	24681	6.6%	351178	93.4%

(χ_2^2 = 1465.683 p = .000)

It is interesting to note that the percentage of fatal accident is significantly lower when the amount of alcohol consumed by the driver is over the legal limit compared with the corresponding percentages with no alcohol or below legal limit or not tested.

6.5.2. Validity of License

Table 6. 13: Validity of License and Severity of Accident

Variable	Categories	Severity of Accident			
		Fatal		Non-Fatal	
		Frequency	Percentage	Frequency	Percentage
Validity of license	Valid license	31363	5.9%	496648	94.1%
	No valid license	191	1.0%	19876	99.0%

(χ^2_1 = 886.503 p = .000)

The results of the table 6.13 reveal that the chi-square test statistic is significant at 95% confidence by confirming that there is significant association between validity of license and severity of accident. Results further confirmed that the percentage of fatal accidents occurrences when have a valid license (5.9%) is significantly higher than that no valid license (1.0%).

6.5.3. Type of Driver Age

Chi-square test statistic in table 6.14 indicates that there is a significant association between age of the driver and severity of accident at 95% confidence level. When comparing three binomial distributions separately, the percentage of occur fatal accidents occurrences when the driver's age 18 - 40 years (5.7%) is significantly higher than when the driver's age 40 - 60 years. Moreover the percentage of fatal accidents occurrences when the driver's age above 60 years (5.8%) is significantly higher than when driver's age fall between 40 - 60 years. Similarly, the percentage of fatal accidents occurrences when the driver's age is less than 18 years (6.5%) is significantly higher than when the driver's age is more than 60 years.

Table 6. 14: Age of Driver and Severity of Accident

Variable	Categories	Severity of Accident			
		Fatal		Non-Fatal	
		Frequency	**Percentage**	**Frequency**	**Percentage**
Age of driver	Less than 18 years	3257	6.5%	47152	93.5%
	18 - 40 years	19784	5.7%	327043	94.3%
	40 - 60 years	7444	5.6%	124923	94.4%
	More than 60 years	1069	5.8%	17406	94.2%

(χ_3^2 = 52.202 p = .000)

6.5.4. Gender of Driver

Table 6. 15: Gender of Driver and Severity of Accident

Variable	Categories	Severity of Accident			
		Fatal		Non-Fatal	
		Frequency	**Percentage**	**Frequency**	**Percentage**
Gender of driver	Male	24577	5.8%	402765	94.2%
	Female	6977	5.8%	113759	94.2%

(χ_1^2 = 0.132 p = .716)

Results of chi-square analysis in table 6.15 reveal that there is no significant association between gender of the driver and severity of accident at 95% confidence.

6.5.5. Type of Key Factors

The results of chi-square test in table 6.16 confirm that there is a significant association between key factors of RTAs and severity of accident with 95% confidence level.

Thus it can be concluded with 95% confidence that the percentage of occur fatal accidents occurrences due to the lack of attention of driver (6.4%) is significantly higher than that occur accidents due to the negligence of pedestrians and other external reasons (5.1%).

Table 6. 16: Key Factors and Severity of Accident

Variable	Categories	Severity of Accident			
		Fatal		Non-Fatal	
		Frequency	**Percentage**	**Frequency**	**Percentage**
Key factors	Accidents due to negligence of pedestrians and other external reasons	13841	5.1%	257632	94.9%
	Accidents due to the lack of attention of the driver	17713	6.4%	258892	93.6%

(χ_1^2 = 430.191 p = .000)

6.6. Determine the Risk Factors Associated with RTAs

On the view of the above statistical analyses carried out separately for each variable, it was found that, except the gender of the driver, all other categorical variables related to road, time & environmental, vehicle, human & accidents characteristics have significant influence on the severity of RTAs separately. Thus, in order to find the combined impact from the best set of the independent variables out of all the significant variables, binary logistics regression was carried out under forward stepwise ward method. The results of the final model are shown in table 6.17. The significant of the Hosmer and Lemeshow test statistic concludes that the fitted model is significant at 5% level.

The results in table 6.17 indicate that the variable, road surface, light condition, location type, sector, type of day, vehicle type, age of vehicle, alcohol test, validity license, age of driver and key factors of RTAs to predict the outcome variable are significantly associated with severity of accidents when all the variables are taken into consideration simultaneously.

Table 6. 17: Variables in the Equation

Variables	B	S.E.	Wald	df	Sig.	Exp(B)
Road Surface (RS)	.104	.022	22.534	1	.000	1.109
Light Condition (LC)			1758.811	2	.000	
LC. Night, improper street lighting	.417	.023	323.069	1	.000	1.518
LC. Night, good street lighting	.510	.013	1658.688	1	.000	1.666
Location Type (LT)			287.800	2	.000	
LT. Junction	-.262	.016	285.407	1	.000	.769
LT. Other	-.019	.021	.817	1	.366	.981
Sector (S)	.641	.013	2515.664	1	.000	1.899
Type of Day (TD)			108.532	2	.000	
TD. Normal weekend	.106	.013	66.056	1	.000	1.112
TD. Holiday	.258	.035	54.515	1	.000	1.294
Vehicle Type (VT)			8.673	2	.013	
VT. Three wheels	-.054	.021	6.806	1	.009	.947
VT. More than three wheels	-.031	.013	5.327	1	.021	.969
Age of Vehicle (AV)			11.051	2	.004	
AV. 10 - 30 years	-.050	.015	10.612	1	.001	.952
AV. More than 30 years	-.060	.073	.668	1	.414	.942
Alcohol Test (AT)			930.797	2	.000	
AT. Over Legal Limit	-.501	.047	111.155	1	.000	.606
AT. Not Tested	.375	.015	630.880	1	.000	1.455
Validity of License (VL)	-1.125	.075	227.001	1	.000	.325
Age of Driver (AD)			18.647	3	.000	
AD. 18 - 40 years	-.070	.020	12.007	1	.001	.932
AD. 40 - 60 years	-.023	.022	1.056	1	.304	.977
AD. More than 60 years	-.019	.037	.264	1	.607	.981
Key Factors (KF)	.090	.012	53.527	1	.000	1.094
Constant	-3.541	.028	16034.845	1	.000	.029

Hosmer and Lemeshow Test Statistic: χ^2_8 = 455.72 (p = .000)

Table 6. 18: Classification based on the Model (1)

Observed		Predicted		
		Type of Accident		Percentage Correct
		Non-Fatal	Fatal	
Type of Accident	Non-Fatal	405011	111513	78.4%
	Fatal	15525	16029	50.8%
Overall Percentage				76.8%

The overall productivity power of the model is 76.8% (Table 6.18). The probability of correctly classifying fatal accidents given that it is fatal accident is .508 against the probability of correctly classifying non-fatal accident given that it is non-fatal is .784.

The results in the table 6.19 of the Cox & Snell R^2 and Nagelkerke R^2 indicate that the explained variation in the dependent variable based on the model varies from 1.5% to 4.3%. Both statistics indicate that the percentage of variance of dependent variable explained by the model. However, various authors have citizen these two indicators

Table 6. 19: Model Summary

Step	-2 Log likelihood	Cox & Snell R^2	Nagelkerke R^2
1	233155.861	.015	.042

Thus the final model for the log odds ratio of fatal accident can be written as:

$$Log\left(\frac{p}{1-p}\right) = -3.541 + .104^{RS} + .417^{\text{LC.Night,improper street lighting}} + .510^{\text{LC. Night,good street lighting}} - .262^{\text{LT.Junction}} + .641^{S} + .106^{\text{TD.Normal weekend}} + .258^{\text{TD.Holiday}} - .054^{\text{VT.Three wheels}} - .031^{\text{VT.More than three wheels}} - .050^{\text{AV.10 − 30 years}} - .501^{\text{AT.Over Legal Limit}} + .375^{\text{AT.Not Tested}} - 1.125^{VL} - .070^{\text{AD.18 − 40 years}} + .090^{KF} \quad ......(1)$$

Thus model for odd ratio can be written as:

$\left(\frac{p}{1-p}\right)$ = 0.029 + 1.109 * RS + 1.518 * LC.Night improper street lighting + 1.666 * LC.Night good street lighting + 0.769 * LT.Junction + 1.899 * S + 1.112 * TD.Normal weekend + 1.294 * TD.Holiday + 0.947 * VT.Three wheels + 0.969 * VT.More than three wheels + 0.952 * AV.10 - 30 years + 0.606 * AT.Over Legal Limit + 1.455 * AT.Not Tested + 0.325 * VL + 0.932 * AD.18 - 46 years + 1.094 * KF..(2)

The probability of fatal accidents can be estimates using

$$p = \frac{XX}{(1+XX)} \quad ......(3)$$

where XX is the,

$$e^{\substack{0.029 + 1.109 * \text{RS} + 1.518 * \text{LC.Night improper street lighting} + 1.666 * \text{LC.Night good street lighting} + 0.769 * \\ * \text{LT.Junction} + 1.899 * \text{S} + 1.112 * \text{TD.Normal weekend} + 1.294 * \text{TD.Holiday} + 0.947 * \text{VT.Three wheels} \\ + 0.969 * \text{VT.More than three wheels} + 0.952 * \text{AV.10} - 30 \text{ years} + 0.606 * \text{AT.Over Legal Limit} + 1.455 * \\ * \text{AT.Not Tested} + 0.325 * \text{VL} + 0.932 * \text{AD.18} - 46 \text{ years} + 1.094 * \text{KF}}}$$

The model (2) indicates that variables wet road surface, light condition where the night with improper street lighting and good street lighting, rural area, normal weekend, holiday, alcohol test not tested, accidents due to lack of attention of driver significantly influence positively on the odd ratio of happen fatal accidents while junction, three wheels and more than three wheels vehicles, age of vehicle 10 - 30 years, alcohol consumption over legal limit, drivers without license, age of driver 18 - 40 years significantly influence negatively on the OR of happen fatal accidents.

Using the equation (2) the following conclusions can be made,

The odds of happening fatal accidents in wet road surface is 1.109 times higher than that it occurs in dry road surface when all other variables in the model are fixed.

The odds of happening fatal accidents during night with improper street lighting is 1.518 times higher than that it occurs during daylight when all other variables are fixed.

The odds of happening fatal accidents during night with good street lighting is 1.666 times higher than that it occurs in daylight when all other variables are fixed.

The odds of occurring fatal accidents in rural area is 1.899 times higher than that of urban area when all other variables are fixed.

The odds of happening fatal accidents in normal weekend is 1.112 times higher than that it occurs in normal working day when all other variables are fixed.

The odds of happening fatal accidents in holiday is 1.294 times higher than that it occurs in normal working days when all other variables are fixed.

The odds of occurring fatal accidents when the alcohol consumption of the driver is not tested is 1.455 times higher than that it occurs when the corresponding percentages with no alcohol or below legal limit when all other variables in the model are fixed.

The odds of happening fatal accidents due to the lack of attention of driver is 1.094 times more likely to occurs compare to fatal accidents due to the negligence of pedestrians and other external reasons.

Using the equation (2) the following conclusions can be made,

p (fatal/ wet road surface, night with improper street lighting, rural area) when p (fatal/wet road surface, night with improper street lighting, urban area) = 0.92

Based on the above results it can be said that the chance of fatal accidents is very high when the road is wet in night with no proper street lighting in rural areas.

6.4. Summary of Chapter Six

When the variables were considered separately, all attributes of road characteristics, time & environmental characteristics and vehicle characteristics, human & accident characteristics have significant association with accident severity except gender of the driver. When all factors considered simultaneously, revealed that wet road surface, night with improper street lighting, night with good street lighting, rural area, normal weekend, holiday, alcohol test not tested, accidents due to the lack of attention of the driver, two wheels vehicles, age of vehicle less than 10 years and driver's age under the age of 18 years have significantly contributed to occurrences of fatal accidents.

CHAPTER 07

CONCLUSIONS, RECOMMENDATIONS AND SUGGESTIONS

Based on the statistical analysis carried out in chapters 4, 5 and 6 the following conclusions and recommendations are given along with few suggestions.

7.1. Conclusions

1. The percentage of fatal accidents have increased from 6.1% (2005 - 2008) to 7.2% (2013 - 2019), while damages have been dropped from 44.1% to 35.5% during the same period.
2. The percentage of grievous accidents have an increasing trend by rising from 14.1% (2005 - 2008) to 21.8% (2013 - 2019), while minor accidents have been dropped from 35.7% to 35.5% during the same period.
3. Pedestrians (29%) and motorcyclists (27%) are more vulnerable road users irrespective of the time period.
4. Percentage of accidents involving motorcycles (25% to 44.5%), three-wheelers (12.6% to 22.9%) and car (10.7% to 18%) have increased during the period from 2005 - 2008 to 2013 - 2019 irrespective of the types of crashes.
5. The percentage of fatal (6% to 7%), grievous (18% to 20%) and minor (35% to 38%) accidents have increased, while damage accidents have dropped from 41% to 35% when moving from Monday to Sunday.
6. Midnight to 4 a.m. is high risk for fatal (10%) and damage (44%) accidents while higher number of grievous (19%) and minor (37%) are reported during evening hours (4 - 8 p.m.).
7. Key factors of RTAs are lack of attention of the driver (overtaking, speed driving, diversion, alcohol consumption) and negligence of pedestrians & other external reasons (mechanical faults, negligence of pedestrians, others).
8. Risk factors associated with fatal RTAs are existence of wet road surface, driving in night (good or improper street lighting), road with no junction within 10 meters, driving in rural areas, driving on the weekends and during holidays, driving two wheels vehicles, driving vehicles that are age of vehicle less than

10 years, the driver being less than 18 years of age and lack of attention of the driver.

7.2. Recommendations

1. Pedestrians should be educated on the use of sidewalks, safe road crossing procedures, and watchfulness while crossing roads.
2. Traffic signalization, pedestrian bridges and pavement tunnels are good alternatives to prevent pedestrian accidents as it allows pedestrians to cross the road without coming to contact with vehicles.
3. Pedestrian crossings that do not have signals should be marked with the D-6 traffic sign, the sign can also be placed on an illuminated or reflective background to enhance visibility.
4. Dynamic or active road signage systems which contains automatic detection of pedestrian activities and activation of lights to alert or warn drivers of pedestrian presence should be in use.
5. Motorcycles are often involved in collisions with other vehicles. Thus it is better to set aside a separate lane for them especially in busy roads. Highlight the presence of motor-cyclists through methods such as leaving the headlamp on even during day-time and wearing bright upper-torso garments.
6. Development of effective training methods to instill collision avoidance braking skills for motor-cyclists and establishment of interconnected brake systems.
7. Installation of traffic signals, street lights, police statues with flashlights and road lighting equipment in rural areas.
8. Establish speed reduction methods to ensure pedestrian safety (establishment of curbed traffic islands placed in the center of a road, at intersections or mid-block, allowing pedestrians to cross in stages while forcing vehicles to slow down), roadway narrowing (curving the alignment of the outer roadway edges at appropriate lengths forcing the drivers to slow down, the visibility of the pedestrians waiting to cross the road is an added advantage) and raised crossing (this has a similar effect as a road hump)
9. Maintenance of high collision concentration locations and hazardous roads.

7.3. Suggestions

1. Encouraging and promoting safe driving behavior among community members by increasing awareness through road safety campaigns.
2. Establishing integrated surveillance systems, spreading information on the burden of road traffic accidents and their causal/risk factors, which helps in developing preventive measures.
3. Enforcement of strict laws by implementing penalty and imprisonment if required for those violating traffic rules.
4. Lane driving should be strictly followed and drivers should be encouraged to use signals.
5. Provide educational programs, with an emphasis on increasing driver's vigilance on pedestrians and the importance of always using a seatbelt while driving, to decrease the severity of RTAs and introduce special driving programmes for school leavers as majority of the three wheel drivers belong to this group.
6. Implementation of proper road maintenance, properly designed road labels, erect road signs and warning signals that suit all climate changes, maintenance of proper road conditions, traffic conditions, and other special road condition requirements and the construction of bumping in appropriate locations along with the removal of all unauthorized bumping on the roads.
7. Enhance traffic police law enforcement to reprimand drivers who are reckless, exhibiting risk taking behaviors in speeding, overtaking, diversions, signal violation, designated lane violation, drunk driving and are not using a seat belt. Enforcements of law should be made particularly more-strict during weekends and holidays as there are frequent fatal and grievous RTAs occurrences during these days.
8. Improve the measures of traffic safety at school zones, hospital areas, and metropolitan areas.
9. All drivers should be given a fitness certificate (a report on the vehicle condition) of the vehicle which should be annually renewed and a workshop

should be carried out for all drivers, where skills in terms of checking the basic conditions of the vehicle will be imparted.

10. Establish speed radars linked to warning signs, variable speed limits and photo enforcement system for exceeding speed limit.
11. Roadway departure systems and driver monitoring system as a solution for accidents due to sleeping or fatigue.

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ANNEXURES

Annexure 1: Deaths Cause Categories in World

Communicable, maternal, perinatal and nutritional conditions	Infectious and parasitic diseases	Tuberculosis	
		STDs excluding HIV	Chlamydia
			Gonorrhea
			Trichomoniasis
			Genital herpes
			Other STD
		HIV/AIDS	HIV resulting in TB
		Diarrhoeal diseases	HIV resulting in other diseases
		Childhood-cluster diseases	Whooping cough
			Diphtheria
			Measles
			Tetanus
		Meningitis	
		Encephalitis	
		Hepatitis	Acute hepatitis A
			Acute hepatitis B
			Acute hepatitis C
			Acute hepatitis E
		Parasitic and vector diseases	Malaria
			Trypanosomiasis
			Chagas disease
			Schistosomiasis
			Leishmaniasis
			Lymphatic filariasis
			Onchocerciasis
			Cysticercosis
			Echinococcosis
			Dengue
			Trachoma
			Yellow fever
			Rabies
		Intestinal nematode infections	Ascariasis
			Trichuriasis
			Hookworm disease
			Food-bourne trematodes
		Leprosy	
		Other infectious diseases	
	Respiratory infectious	Lower respiratory infections	
		Upper respiratory infections	
		Otitis media	
	Maternal conditions		
	Neonatal conditions	Preterm birth complications	
	Neonatal conditions	Birth asphyxia and birth trauma	

		Neonatal sepsis and infections	
		Other neonatal conditions	
Communicable, maternal, perinatal and nutritional conditions	Nutritional deficiencies	Protein-energy malnutrition	
		Iodine deficiency	
		Vitamin A deficiency	
		Iron-deficiency anaemia	
		Other nutritional deficiencies	
Non - communicable diseases	Malignant neoplasms	Mouth and oropharynx cancers	Lip and oral cavity
			Nasopharynx
			Other pharynx
		Oesophagus cancer	
		Stomach cancer	
		Colon and rectum cancers	
		Liver cancer	
		Pancreas cancer	
		Trachea, bronchus, lung cancers	
		Melanoma and other skin cancers	Malignant skin melanoma
			Non-melanoma skin cancer
		Breast cancer	
		Cervix uteri cancer	
		Corpus uteri cancer	
		Ovary cancer	
		Prostate cancer	
		Prostate cancer	
		Kidney, renal pelvis and ureter cancer	
		Bladder cancer	
		Brain and nervous system cancers	
		Gallbladder and biliary tract cancer	
		Larynx cancer	
		Thyroid cancer	
		Mesothelioma	
		Lymphomas, multiple myeloma	Hodgkin lymphoma
			Non-Hodgkin lymphoma
			Multiple myeloma
		Leukaemia	
		Other malignant neoplasms	
	Other neoplasms		
	Diabetes mellitus		
	Endocrine, blood, immune disorders	Thalassemia	
		Sickle cell disorders and trait	
		Other haemoglobinopathies and haemolytic anaemia	
		Other endocrine, blood and immune disorders	
	Mental and substance use disorders	Depressive disorders	Major depressive disorder
			Dysthymia
		Bipolar disorder	

		Schizophrenia	
		Alcohol use disorders	
		Drug use disorders	Opioid use disorders
Non - communicable diseases	Mental and substance use disorders	Drug use disorders	Cocaine use disorders
			Amphetamine use disorders
			Cannabis use disorders
			Other drug use disorders
		Anxiety disorders	
		Eating disorders	
		Autism and Asperger syndrome	
		Childhood behavioral disorders	Attention deficit/hyperactivity syndrome
			Conduct disorder
		Idiopathic intellectual disability	
		Other mental and behavioral disorders	
	Neurological conditions	Alzheimer disease and other dementias	
		Parkinson disease	
		Epilepsy	
		Multiple sclerosis	
		Migraine	
		Non-migraine headache	
		Other neurological conditions	
	Sense organ diseases	Glaucoma	
		Cataracts	
		Uncorrected refractive errors	
		Macular degeneration	
		Other vision loss	
		Other hearing loss	
		Other sense organ disorders	
	Cardiovascular diseases	Rheumatic heart disease	
		Hypertensive heart disease	
		Ischaemic heart disease	
		Stroke	
		Cardiomyopathy, myocarditis, endocarditis Other circulatory diseases	
	Respiratory diseases	Chronic obstructive pulmonary disease	
		Asthma	
		Other respiratory diseases	
	Digestive diseases	Peptic ulcer disease	
		Cirrhosis of the liver	
		Appendicitis	
	Digestive diseases	Gastritis and duodeniti	
	Digestive diseases	Paralytic ileus and intestinal obstruction	
		Inflammatory bowel disease	
		Gallbladder and biliary diseases	
		Pancreatitis	
		Other digestive diseases	

	Genitourinary diseases	Kidney diseases	Acute glomerulonephritis
Non - communicable diseases	Genitourinary diseases	Kidney diseases	Chronic kidney disease due to diabetes
			Other chronic kidney disease
		Benign prostatic hyperplasia	
		Urolithiasis	
		Other urinary diseases	
		Infertility	
		Gynecological diseases	
	Skin diseases		
	Musculoskeletal diseases	Rheumatoid arthritis	
		Osteoarthritis	
		Gout	
		Back and neck pain	
		Other musculoskeletal disorders	
	Congenital anomalies	Neural tube defects	
		Cleft lip and cleft palate	
		Down syndrome	
		Congenital heart anomalies	
		Other chromosomal anomalies	
		Other congenital anomalies	
	Oral conditions	Dental caries	
		Periodontal disease	
		Edentulism	
		Other oral disorders	
	Sudden infant death syndrome		
Injuries	**Unintentional injuries**	**Road injury**	
		Poisonings	
		Falls	
		Fire, heat and hot substances	
		Drowning	
		Exposure to mechanical forces	
		Natural disasters	
		Other unintentional injuries	
	Intentional injuries	Self-harm	
		Interpersonal violence	
		Collective violence and legal intervention	

Source: WHO (2018c)

Annexure 2: Trend in Health – Related SDG Indicators

(pink)	Reproductive, Maternal and Child Health
(yellow)	Infectious and Non-Communicable Diseases
(green)	Injuries, Violence and Environmental Risks
(blue)	Health System and Financing

SDG Indicators with Explicit Targets for 2030

Progress stalled or trend in wrong direction	
3.6.1	**Road traffic mortality**
Progress made but too slow to meet target	
3.1.1	Maternal mortality
3.4.1	NCD mortality
3.4.2	Suicide mortality
6.1.1	Safe drinking-water coverage
6.2.1	Safe sanitation coverage
7.1.2	Clean energy coverage
Clean energy coverage	
3.2.1	Under-5 mortality
3.2.2	Neonatal mortality
Progress stalled or trend in wrong direction	
2.2.2	Children overweight
3.3.3	Malaria incidence
3.5.2	Alcohol consumption
6.a.1	Water sector ODA
Progress made	
3.1.2	Skilled birth attendance
3.7.1	Met need for family planning
3.7.2	Adolescent birth rate
2.2.1	Stunting in children
3.b.1	DTP3 coverage
	MCV2 coverage
	PCV3 coverage
3.3.1	New HIV infections
3.3.2	Tuberculosis incidence
3.3.4	Hepatitis B prevalence
3.3.5	Need for NTD interventions
3.a.1	Tobacco use in persons ≥15 years
16.1.1	Homicide

3.9.3	Poisoning mortality
3.b.2	ODA medical research & basic health sectors
1.a.2	Domestic government health expenditure
Trend not yet reported	
2.2.2	Wasting in children
3.9.1	Air pollution mortality
3.9.2	Unsafe water and sanitation mortality
5.2.1	Intimate partner violence
11.6.2	Fine particulate matter in urban areas
3.8.1	UHC service coverage index
3.c.1	Medical doctor density
	Nurse/midwife density
	Dentist density
	Pharmacist density
3.d.1	International Health Regulations capacity
3.8.2	Household health expenditures >10%
	Household health expenditures >25%
17.9.2	Completeness of cause-of-death data

Source: WHO (2019)